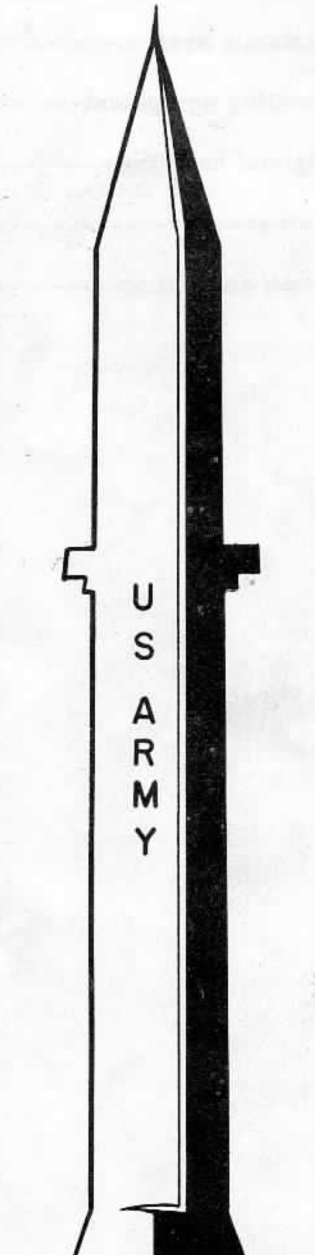
THE REDSTONE

MISSILE SYSTEM



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Section I. INTRODUCTION

1. GENERAL

The Redstone is the Army's largest and longest range tactically operational field artillery guided missile. The missile has a rocket-type propulsion system which uses two liquid propellants, alcohol and liquid oxygen, which are pump fed into the motor by a hydrogen peroxide operated turbine. The guidance system is an inertial type, preset prior to firing, which automatically guides the missile to the target and corrects the trajectory as necessary to insure an adequate circular probable error (CPE).

2. CHARACTERISTICS

The major characteristics and physical dimensions of the missile are as follows:

Length	21.1 meters (69'4")
Diameter	1.8 meters (70")
Loaded weight	61,700 pounds
Empty weight	16,300 pounds
Range (maximum)	200 statute miles
Propellants:	
Oxidizer	Liquid oxygen, 25,000 pounds
Fuel	75 percent alcohol + 25 percent water, 19,000 pounds
Steam source	Hydrogen peroxide, 790 pounds
Thrust	78,000 pounds for 96 to 117 seconds
Guidance	Inertial
Warhead	Nuclear, 7,900 pounds total nose section weight
Mobility	100 percent

3. MISSILE DESCRIPTION

The missile consists of a thrust unit and a body (fig 1). The thrust unit includes the tail section which has 4 fixed stabilizers, 4 movable rudders, and 4 jet vanes which extend into the rocket exhaust to provide control of the missile until its speed is sufficient to cause the external rudders to be effective. Inside the tail section is the rocket engine (fig 2) which produces 78,000 pounds of thrust and a propellant pumping system operated by hydrogen peroxide, a chemical which readily decomposes into steam. Above the tail section is the oxidizer tank which is loaded with 25,000 pounds of liquid oxygen. Above the oxidizer tank is the fuel tank loaded with 19,000 pounds of an alcohol-water solution. The thrust and body units are joined by six bolts which contain internal explosive charges. Shortly after shutoff of the propulsion system, these bolts are destroyed and the two units are pushed apart by two

air-loaded pistons. To keep the missile weight as low as possible, only the body unit is made strong enough to withstand the forces created when the missile reenters the dense atmosphere as it descends to the target. The lower portion of the body contains the guidance system (fig 3). The guidance system is called an "inertial" type system and operates on information from accelerometers which measure the movements of the missile. The accelerometers are mounted on a stabilized platform which is kept in proper orientation by gyroscopes. The angular position of the missile about its center of gravity is measured by the relative movement between the missile and the platform. A tape recorder contains most of the trajectory data although some data is set directly into the computers. At the base of the body are four vanes which control the body unit after separation. The nose unit, weighing 7,900 pounds, contains a nuclear warhead.

4. FIRING DATA OPERATIONS

The early handling procedures and equipment for the preparation and firing of the missile included the use of a mobile crane which was used to position the missile units for assembly, to erect the missile, and to raise men and equipment up the side of the erected missile if repairs or adjustments were required. Since the crane is not air transportable, a lightweight erector-servicer was designed to replace the crane (fig 4). The erector-servicer consists of a modified $2\frac{1}{2}$-ton truck, an H-frame, an A-frame, and cabling. The set is carried on the bed of the $2\frac{1}{2}$-ton truck which also tows the launcher. The launcher is emplaced over the preselected location and the erector-servicer is assembled between the launcher and the truck. All firing area operations take place in the vicinity of the launcher.

a. Assembly. The missile arrives in three units--a nose unit (warhead), an aft unit (guidance compartment), and a thrust unit. The body is assembled first by lifting the aft unit from its trailer, removing the trailer, and positioning the nose unit to permit the two units to be joined. Then the body is released from the hoists and the trailer with the body is pulled out of the immediate area. The thrust unit trailer is backed into position, and the thrust unit is picked up by using the hoists. The thrust unit trailer is driven away, and the body is positioned to join the two units with six bolts containing the internal explosive charges.

b. Horizontal Checkout. The missile is then given a horizontal checkout to assure proper operation of its guidance and propulsion system.

c. Erection. To erect the missile, the truck winch is operated to pull the cable attached to the A-frame. The A-frame rotates about pivot points on the launcher. Cables lead from the A-frame to the missile. The missile nose is lifted with the aft end rotating on pivots on the launcher. As the missile approaches the vertical position, hydraulically operated pistons, mounted on the launcher, engage the missile and slowly lower the missile to the erect position. This prevents the missile from tumbling over the launcher. Then the cables are released and the H-frame repositioned to provide a servicing platform in case repairs or replacements are required in the guidance system.

d. Laying. The missile is then oriented on the firing azimuth by rotating the upper platform on the launcher. Theodolites are used to provide the reference direction.

e. Vertical Checkout. The missile is then given a vertical checkout including fire mission presettings.

f. Propellant Loading. Immediately after the initial laying of the missile, the propellants are pumped into the missile. The alcohol is carried in a 3,000-gallon trailer resembling a gasoline trailer. A pump located in the compartment at the rear of the truck is used to transfer the alcohol into the missile. Two liquid oxygen (LOX) trailers, each with a capacity

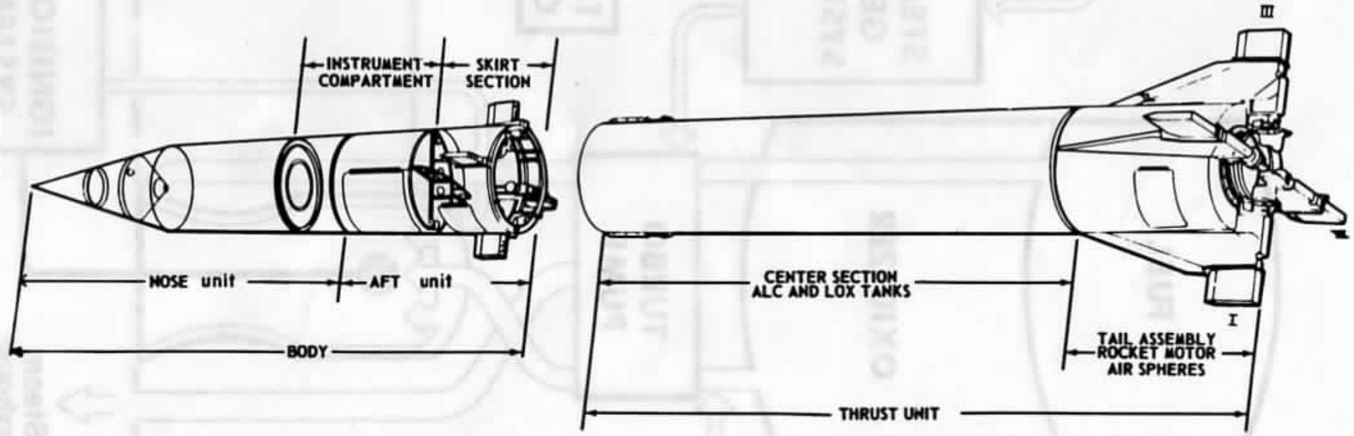

Figure 1. Missile component nomenclature.

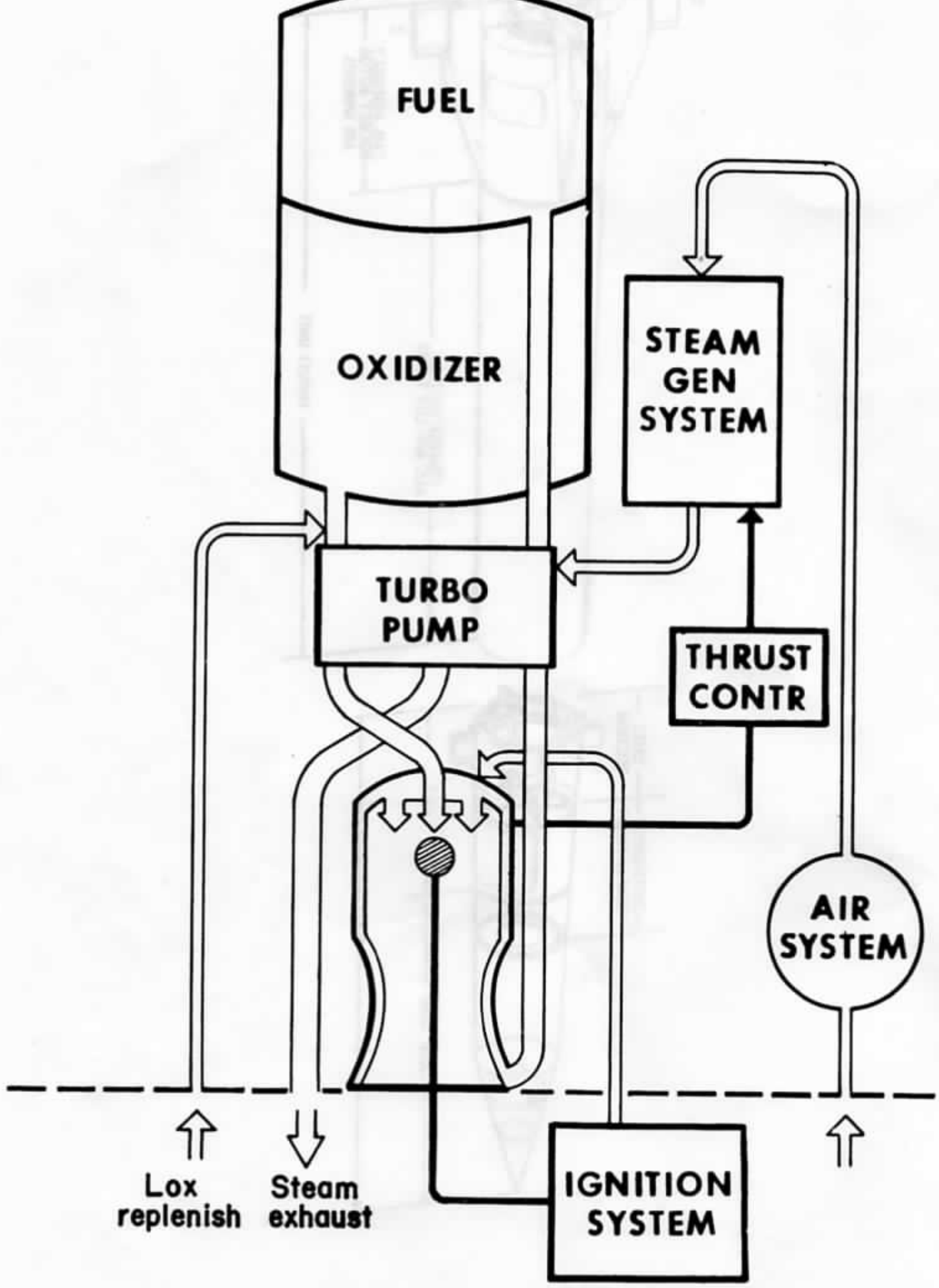

Figure 2. Propulsion system (block diagram).

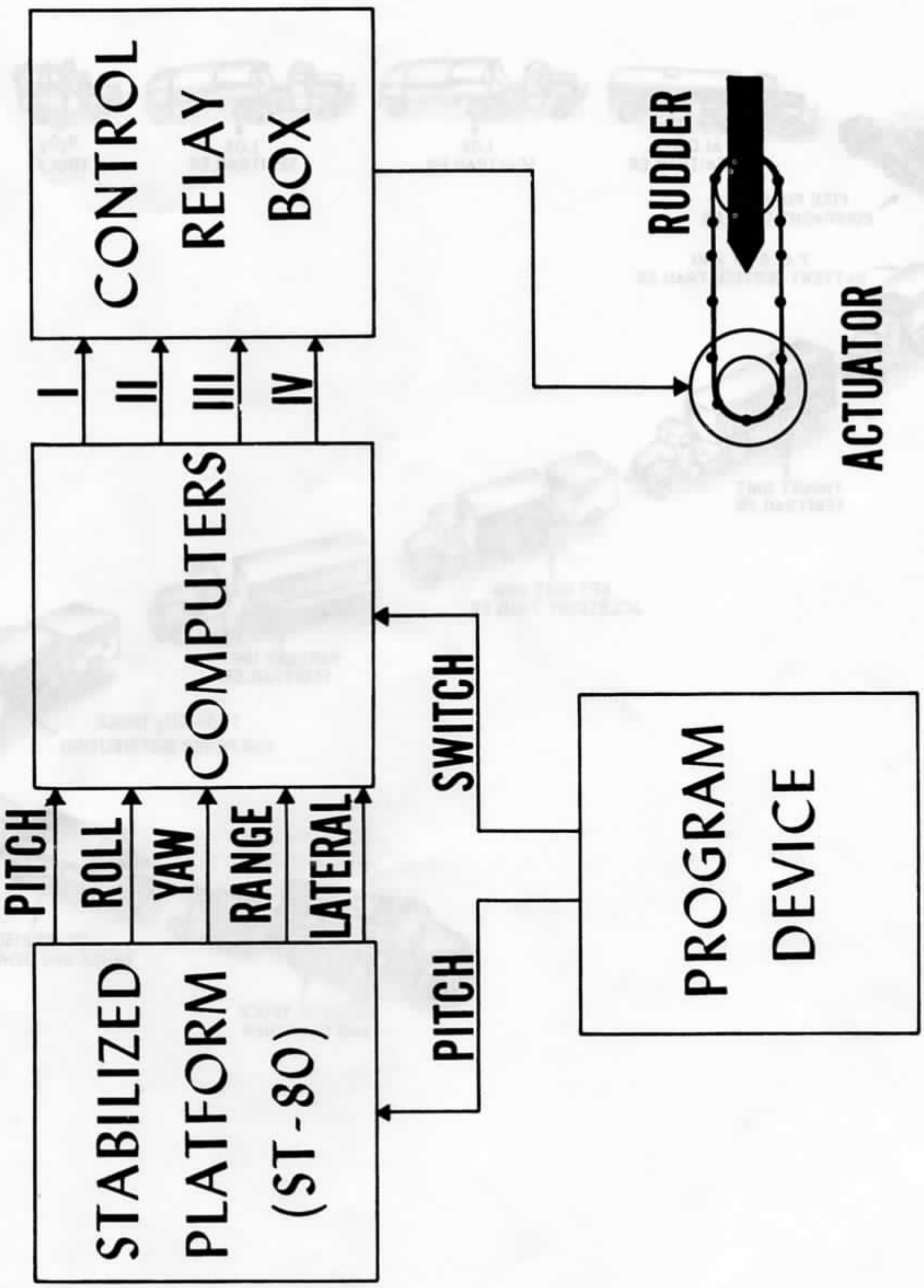

Figure 3. Guidance system (block diagram).

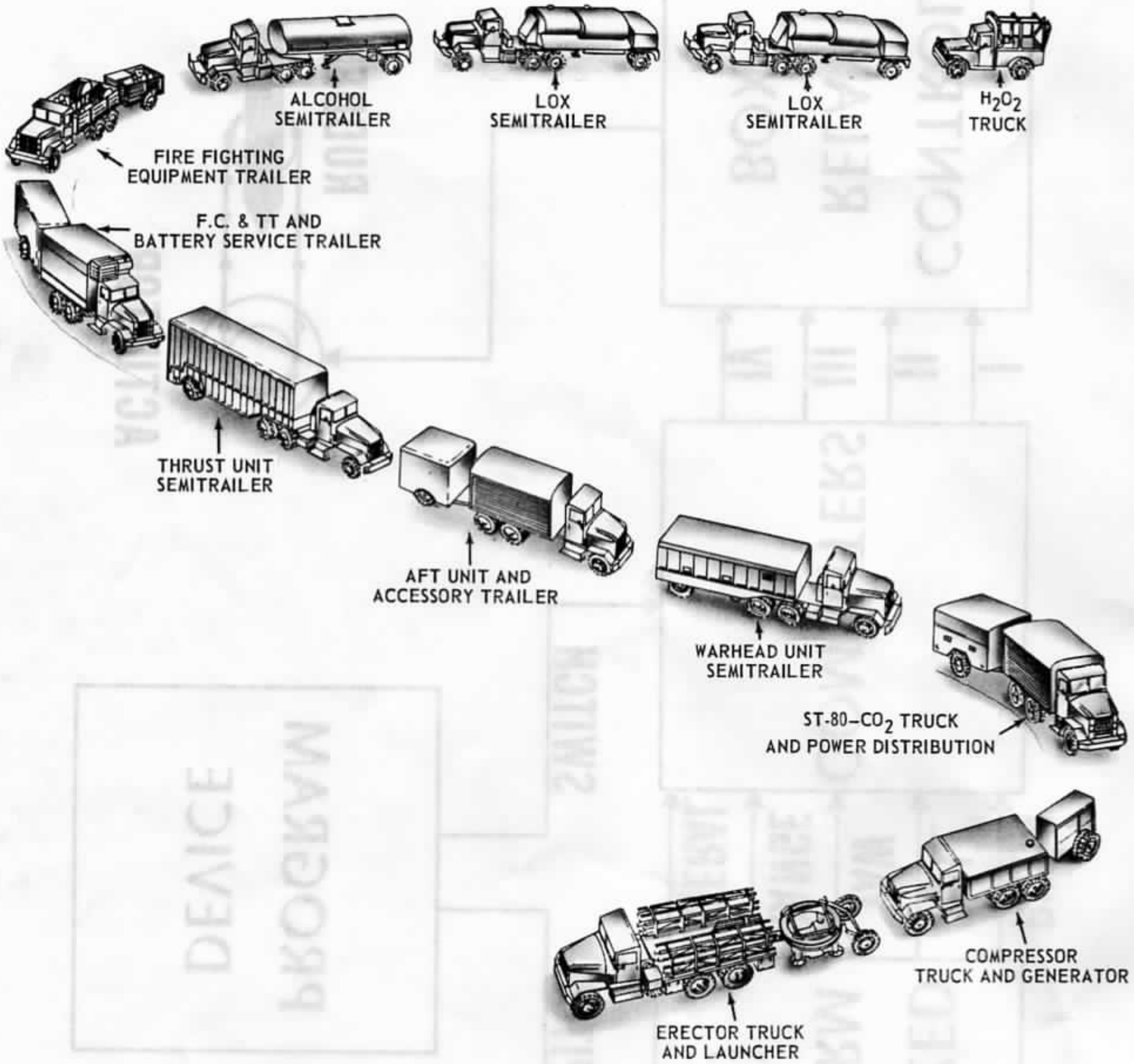

Figure 4. Redstone handling equipment.

of 9 tons, are required to load the missile and to replace the LOX which evaporates prior to firing. The LOX trailers have a special thermos bottle construction to keep the LOX from warming up. LOX exists only at temperatures below minus 297° F. When it warms up above that temperature, it evaporates. Hydrogen peroxide (H_2O_2) to operate the propellant pumping system is then pumped into the missile. The hydrogen peroxide is carried in a 78-gallon drum, mounted on a modified 3/4-ton truck.

g. Missile Firing. The Redstone is fired from a remote firing panel located about 180 meters from the launcher. The firing switch turns on the propulsion system. If initial ignition is satisfactory, the hydrogen peroxide is forced into a reaction chamber to create steam for operation of a turbine to which the propellant pumps are connected. A thrust of 78,000 pounds lifts the missile from the launcher and accelerates it toward the target. The missile rises vertically for a few seconds; then the guidance system automatically pitches the missile on a ballistic path. When the missile has attained the position and velocity to coast on to the target, the propulsion system is turned off by the guidance system. A few seconds later the missile separates into two units. The body unit is guided as necessary to insure a high impact accuracy.

Section II. THE REDSTONE PROPULSION SYSTEM

5. GENERAL

The Redstone guided missile utilizes a bipropellant, pump-fed, liquid rocket propulsion system. The components of the propulsion system are located in the thrust unit of the missile (fig 5). The Redstone uses an alcohol-water solution for fuel with liquid oxygen (lox) as the oxidizer. The propellant pumps are powered by a steam driven turbine. The steam is generated onboard the missile by the decomposition of hydrogen peroxide into super heated steam. The steam is routed through turbine blades that drive the propellant pumps. Various valves of the propulsion system are operated by high pressure air. High pressure air is also used to maintain a slight pressure on the fuel tank; the oxidizer tank is self-pressurized by the evaporation of LOX. Initial ignition is accomplished by injecting igniter alcohol from an external source into the combustion chamber where it is combined with liquid oxygen. This mixture is ignited by an electrically energized squib. With successful initial ignition, alcohol from the missile alcohol tank is applied to the combustion chamber. The design of the combustion chamber and nozzle of the rocket motor is such that the thermal energy of the burning propellants is converted to kinetic energy. The thrust or forward propulsive force is proportional to the kinetic energy. The thrust produced by the rocket motor is held at a constant value by maintaining a constant pressure within the combustion chamber. Any change in pressure in the combustion chamber is sensed and converted into an electrical signal that results in a change in the speed of the propellant pumps. This changes the quantity of propellants consumed each second to the value which creates the correct chamber pressure and the correct thrust. Thrust is terminated at the desired time by stopping the flow of propellants to the motor and stopping the flow of hydrogen peroxide to the steam generator. The propulsion system of the Redstone missile includes the following major components and systems:

a. Pneumatic system.

b. Electrical system.

c. Rocket engine.

d. Fuel system.

e. Oxidizer system.

f. Steam generating system.

g. Ignition system.

Note. In the following description of the propulsion system, all figures are approximations. This has been done to help generalize the scope of discussion.

6. PNEUMATIC SYSTEM

A supply of high pressure air is carried in six spheres mounted in the missile tail section (fig 5). These spheres are charged prior to takeoff to 3,000 pounds per square inch (psi). Air from these spheres, after passing through the heat exchanger, maintains a slight pressure in the alcohol tank. High pressure air is also supplied to a pneumatic panel where pressure is controlled by regulators and valves and distributed to pressurize the hydrogen peroxide (H_2O_2) system and operate various propellant control valves (fig 6).

7. ELECTRICAL SYSTEM

The electric power required by the propulsion system is derived from three sources.

a. Batteries. A 28-volt direct-current (d-c) power is supplied by batteries located in the missile body guidance compartment. This power is routed to various relays and rocket engine controls which provide automatic sequencing of engine ignition and shutoff operations.

b. Ground Source. A 120-volt, 60-cycle alternating-current (a-c) power is supplied by a ground source prior to firing to operate various heaters in the propulsion system.

c. Generator. A 115-volt, 400-cycle alternating-current power is supplied by a generator in the missile body unit to operate the thrust controller. The generator transforms the 28-volts direct current from the missile batteries to alternating current.

8. ROCKET ENGINE

The Redstone missile is powered by a liquid bipropellant rocket engine (fig 7) rated to provide a nominal thrust of 78,000 pounds. The capacity of the missile propellant tanks limits burning time to a maximum of 117 seconds. Operation is by the continuous injection and combustion of fuel and oxidizer. The rocket engine is very simple in construction. It has a large, cylindrical, double walled combustion chamber, open at one end for escape of the powerfully expanding gases and closed off at the forward end by a perforated injector plate. Alcohol and liquid oxygen are forced through the perforations under pressure and atomized, mixed, and ignited just behind the plate. Started electrically, ignition occurs along a broad flame front covering the full cross sectional area of the chamber. The burning gases expand violently and gain velocity, rushing to escape through the narrow throat of the chamber. Additional thrust is delivered when the gases surge into the flaring exhaust nozzle, expand still more, and emerge as a white-hot jet stream.

9. FUEL SYSTEM (FIG 6)

The alcohol tank is filled with 19,000 pounds of an alcohol-water solution when the missile is in the vertical position. The 25 percent water content of the fuel reduces the flame temperature so that the engine will not melt and adds to the weight and pressures of gases expelled, thus contributing to thrust. Prior to alcohol loading, 10 gallons of water as an inert lead start are placed in the rocket motor manifold. During ignition, this water is forced into the combustion chamber ahead of the main alcohol flow to reduce the violence of main-stage ignition. The alcohol tank is pressurized to 20 pounds per square inch by air from the

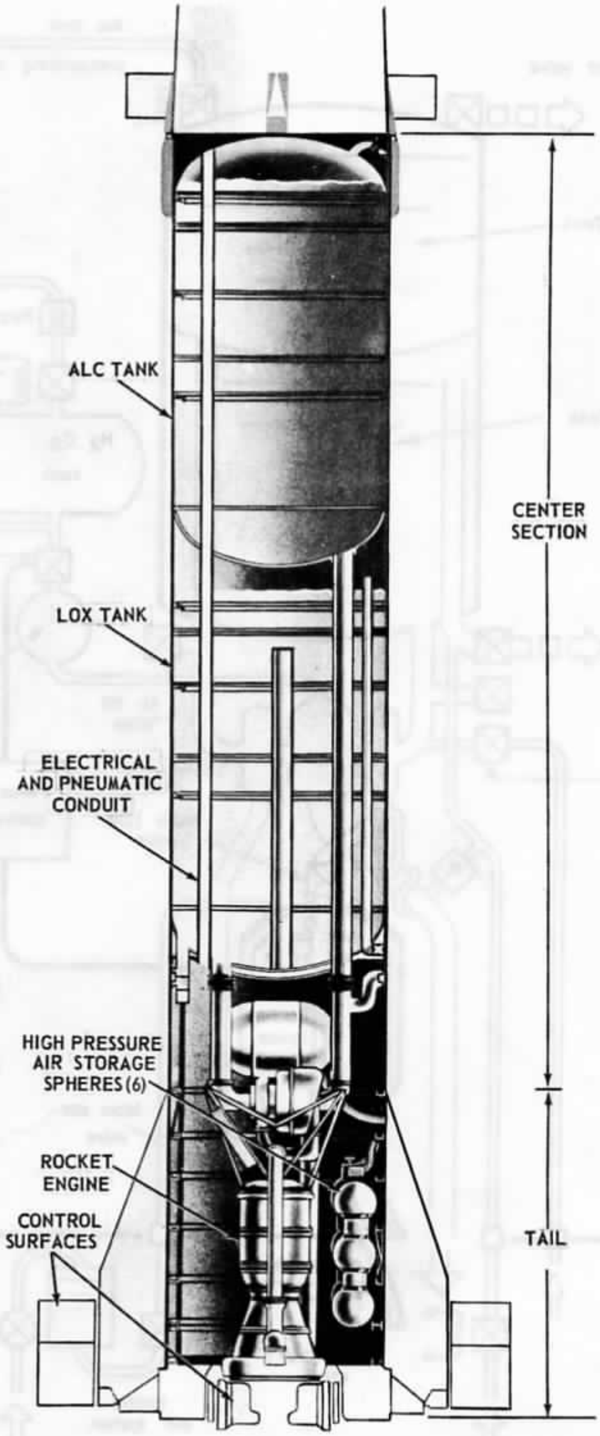

Figure 5. Thrust unit.

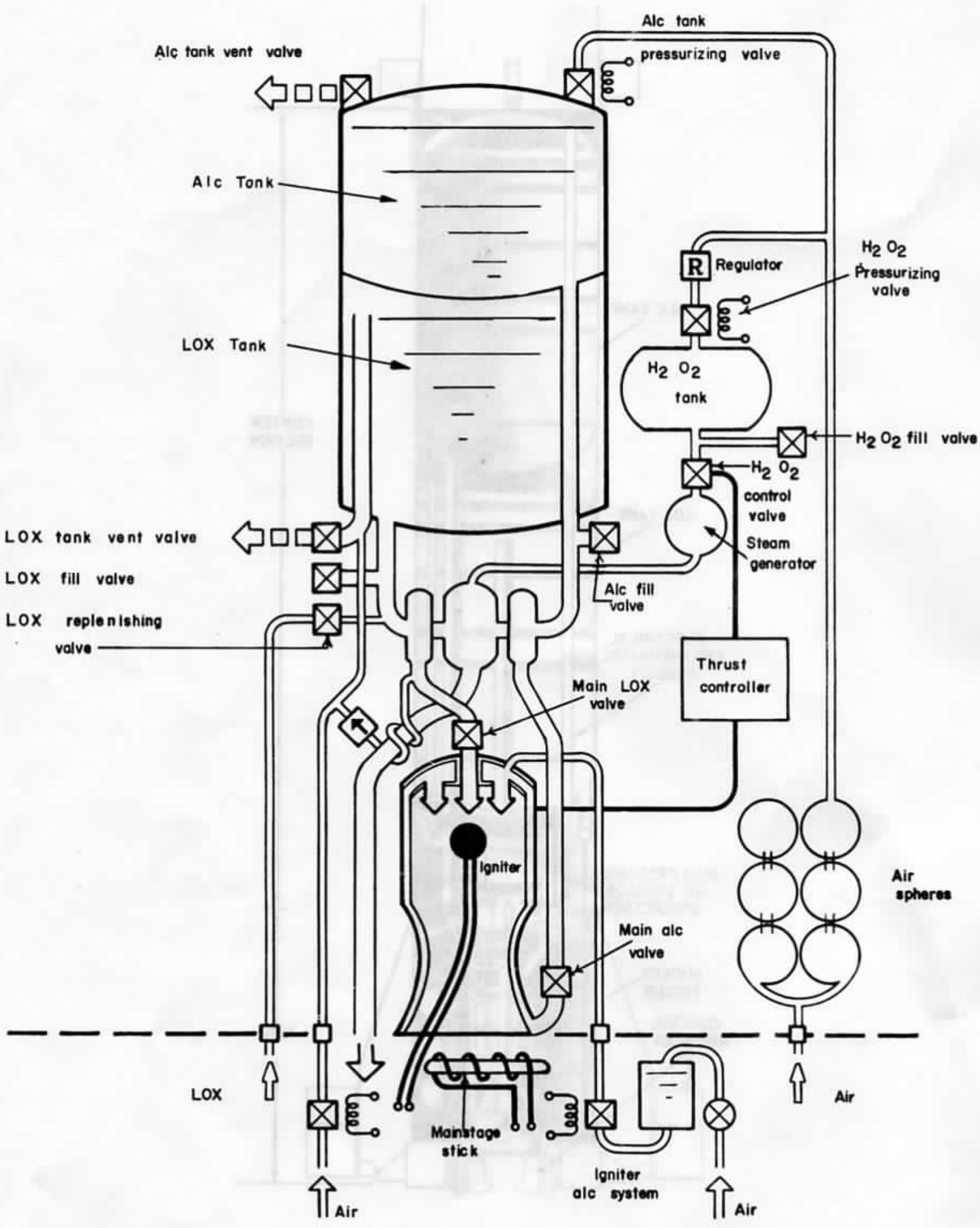

Figure 6. Propulsion system (functional schematic).

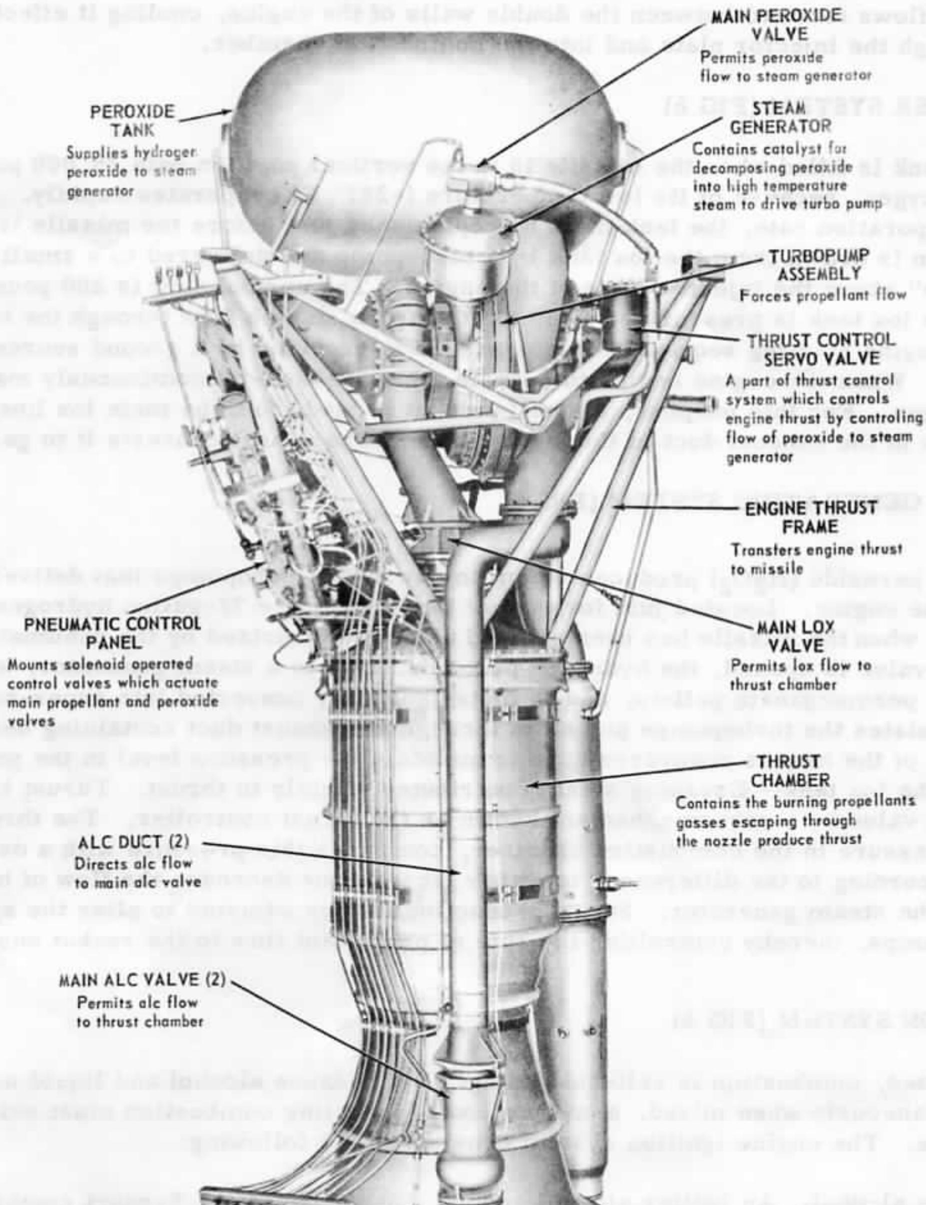

Figure 7. Rocket engine.

high pressure spheres. The turbo-pump draws 150 pounds of fuel per second from the tank and forces it through dual ducts to a manifold encircling the engine exhaust nozzle. The alcohol then flows forward between the double walls of the engine, cooling it effectively, and passes through the injector plate and into the combustion chamber.

10. OXIDIZER SYSTEM (FIG 6)

The lox tank is filled when the missile is in the vertical position with 25, 000 pounds of lox. The liquid oxygen, because of its low temperature (-297° F) evaporates rapidly. Because of this high evaporation rate, the tank must be replenished just before the missile is fired. Liquid oxygen is drawn from the lox tank by a turbopump and delivered to a small reservoir or "lox dome" above the injector plate of the engine. The normal flow is 200 pounds per second. The lox tank is pressurized to 30 psi to insure smooth flow through the turbopump. During the engine starting sequence, this pressure is provided by a ground source of compressed air. When the engine begins to operate, this pressure is continuously maintained by gaseous oxygen. For this purpose, a small amount is bled from the main lox line and passed through coils in the exhaust duct of the steam system where heat converts it to gas.

11. STEAM GENERATING SYSTEM (FIG 6)

Hydrogen peroxide (H_2O_2) produces steam to power the turbopumps that deliver the propellants to the engine. Located just forward of the engine, the 72-gallon hydrogen-peroxide tank is filled when the missile has been erected and is pressurized by the pneumatic system. When a feed valve is opened, the hydrogen peroxide flows to a steam generator, strikes a bed of potassium permanganate pellets, and is instantaneously converted into super-heated steam. The steam rotates the turbopumps and exits through an exhaust duct containing heat exchanger coils. Some of the heat is recovered here to maintain the pressure level in the pneumatic system and the lox tank. Escaping steam contributes slightly to thrust. Thrust is maintained at a constant value by a servomechanism known as the thrust controller. The thrust controller measures pressure in the combustion chamber, compares this pressure with a desired value, and acts, according to the difference, to either increase or decrease the flow of hydrogen peroxide to the steam generator. Steam production is thus adjusted to alter the speed of the propellant pumps, thereby controlling the rate of propellant flow to the rocket engine.

12. IGNITION SYSTEM (FIG 6)

Once started, combustion is self-sustaining. But because alcohol and liquid oxygen do not ignite sponstaneously when mixed, some method of initiating combustion must exist in the rocket engine. The engine ignition system consists of the following:

a. Igniter alcohol. An igniter alcohol supply, consisting of a 3. 5-quart container mounted on the missile launcher, is pressurized during the missile preparation sequence. Alcohol from this container is forced at the proper time through the valve box and multiple coupling to the center ring of the rocket engine injector plate which functions much like a shower head.

b. Igniter Cartridge. An igniter cartridge assembly, consisting of two electrically fired pyrotechnic squibs with a burning time of 10 seconds, initiates combustion. This assembly is suspended beneath the injector head by means of a thin plastic rod which screws into the injector head prior to firing.

c. Ignition Sensing Device. An ignition sensing device commonly called the mainstage stick is installed below the rocket engine nozzle. This device has a loop of wire which extends into the jet steam of the engine. With proper ignition, the wire will burn in two, generating an electrical signal which causes the main alcohol valves to open and the turbopump to activate.

13. ROCKET ENGINE OPERATION (FIG 6)

The following events occur automatically upon actuation of the firing circuit from the remote firing panel. Some of these events occur simultaneously.

a. Alcohol and hydrogen peroxide tanks pressurize.

b. When the alcohol tank is pressurized, lox tank pressurization from the ground high pressure air supply begins. (It takes approximately $7\frac{1}{2}$ seconds from the time the fire switch is pressed for the lox tank to pressurize.)

c. The igniter squibs are energized, and the cartridges begin to burn in the igniter assembly. The igniter link burns through.

d. The main lox valve opens. Lox flow to the rocket engine is caused by gravity and tank pressurization (b above).

e. Alcohol from the igniter alcohol container is forced through the center ring of the injector head into the combustion chamber.

f. Combustion begins with excess oxygen.

g. The main stage stick senses the ignition and causes the main alcohol valves to open, and alcohol flows into the manifold and up through the combustion chamber walls forcing the inert lead start (water) into the chamber.

h. The hydrogen peroxide valve opens to admit this chemical to the steam generator.

i. Steam is produced to drive the turbine. The turbo pump accelerates.

j. Thrust rises rapidly as the flow of liquid oxygen and alcohol increases.

k. Admission of gaseous oxygen into the lox tank maintains constant pressurization.

l. The turbopump attains rated speed (4,800 rpm).

m. Full thrust is developed. (When the thrust developed exceeds the weight of the missile, the missile leaves the launcher.)

14. CUTOFF

At the proper time, depending on the range to the target, thrust is terminated by stopping the flow of propellants to the engine and by stopping the power to the turbine. After motor cutoff, the propulsion system serves no function.

Section III. THE REDSTONE GUIDANCE SYSTEM

15. GENERAL

The Redstone guidance system maintains proper angular orientation of the missile; senses, measures, and corrects deviations from the predetermined flight path; and determines the point at which thrust will be terminated. The guidance system is of the inertial type; that is, a system completely self-contained, depending on no other information other than errors generated as a result of positive or negative changes in velocity. These velocity changes can occur in either one of two measuring planes-- a lateral plane or a range plane. The missile guidance system has two types of control-- attitude control and path control.

a. Attitude control. Attitude is the angular position of the missile with respect to its center of gravity. The terms used to define attitude are roll, pitch, and yaw. Roll is the angular orientation of the missile about an axis drawn longitudinally through the center of the missile. With the missile in a horizontal position, yaw is the orientation of the missile about an axis perpendicular to the horizon and may be clockwise (to the right) or counterclockwise (to the left) of the desired orientation, as seen from above the missile. Pitch is the orientation as seen from the side and may be up or down.

b. Path Control. Guidance or path control is the determination and control of the missile's position with respect to its references. Range guidance is in the direction of the target and, in the Redstone system, is measured along a line perpendicular to the tangent of the trajectory at impact (fig 8). The other reference direction is lateral --the displacement right or left of the azimuth between the launcher and target.

c. Components. To satisfy the requirements for attitude and path control, self-contained equipment must measure the performance of the missile, determine the amount of deviation from the desired conditions, form corrective commands, and then reposition the missile as necessary. The Redstone guidance system consists of a stabilized platform as a reference, accelerometers to measure the performance, computers to determine corrective commands, a relay box to apply battery power to the motor actuators which position the rudders as required, and the necessary feedback circuits to provide additional stability and prevent overcontrol (fig 9). The heart of the guidance system is the ST-80, the stabilized platform. The stabilized platform is automatically leveled and alined before firing and maintains that orientation until impact. Three gyroscopes mounted on the platform maintain its proper orientation.

16. ATTITUDE CONTROL

a. General. One of the guidance requirements, that of attitude control, is accomplished by potentiometers (voltage measuring devices) mounted between the platform and the missile frame. If the missile develops a roll, yaw, or pitch error, the angle error between the platform and missile frame is electrically measured and the signals are fed into the control computer. The error signals are mixed in the control computer to produce outputs which are used to reposition the missile. During the powered-flight phase, the combined effects of the jet vanes in the exhaust stream of the rocket motor and air rudders on the thrust unit produce the necessary control torques. During travel through the midcourse portion of the trajectory (which is essentially out of the atmosphere), a system of air jet nozzles using high pressure air produces the necessary control forces. During the terminal portion of the trajectory, air vanes located on the aft end of the body produce the attitude control.

b. Pitch Programming. Since the missile is launched from the vertical position, the missile must be steered into a ballistic trajectory; therefore, a timed pitch program is introduced into the control system to cause the missile to assume the correct attitude which is approximately tangent to the trajectory. Timing for signal ratio changes and other functions along the missile trajectory is stored in the form of pulses on a magnetic tape. This tape is run through a missile-borne playback unit. This unit feeds the pulses into the stabilized platform to initiate the action of a stepmotor which displaces the wiper arm of the pitch potentiometer on the stabilized platform. This action is sensed as an error and in correcting for this deliberate pitch wiper displacement, the missile is pitched so that the potentiometer wiper is brought back to the zero position, thus pitching the missile toward the target. Since the program is different for various trajectories, the proper program corresponding to the desired trajectory is imposed on the missile tape from a program recording system in the fire control and test truck. Tapes for different trajectories are from a library of tapes carried by the firing battery.

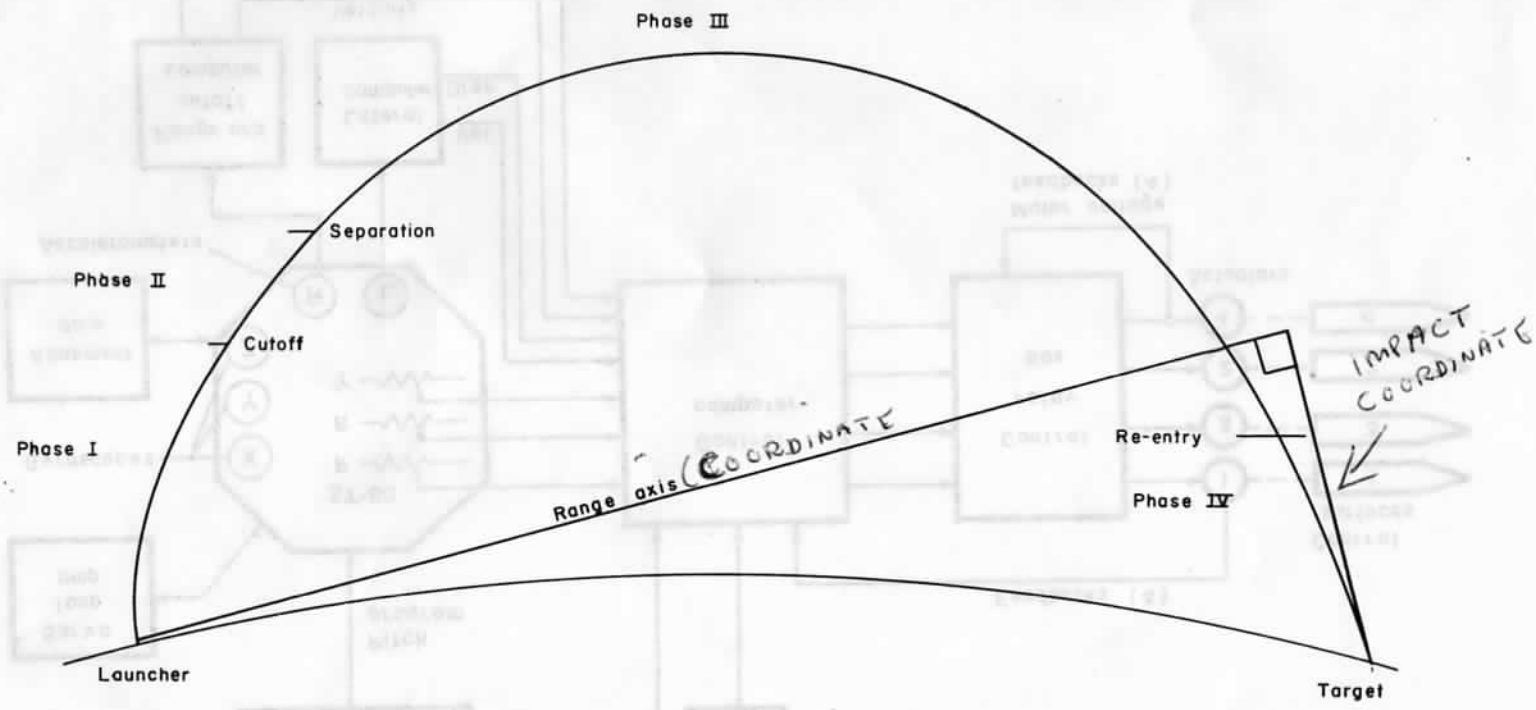

Figure 8. Redstone trajectory.

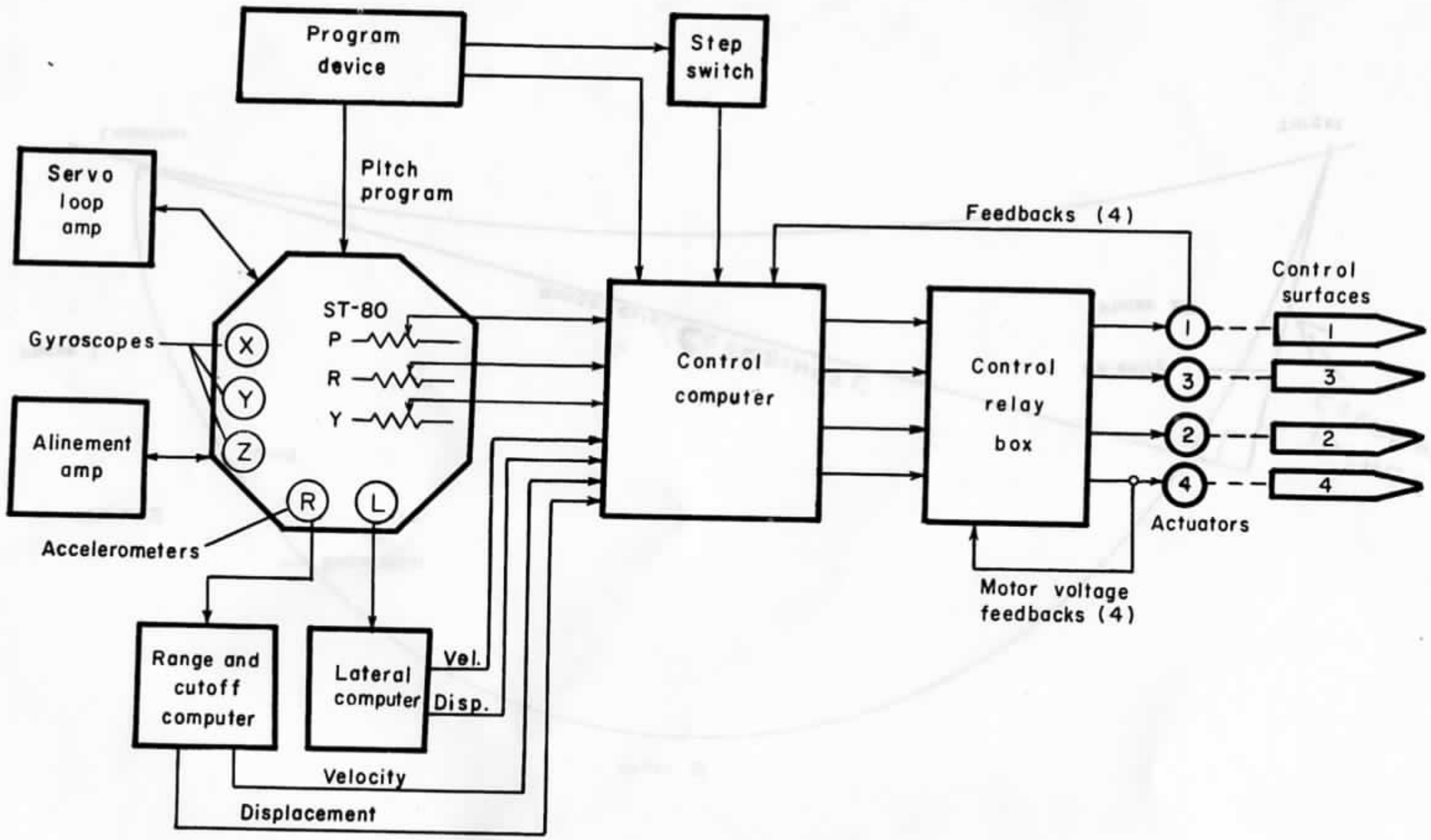

Figure 9. Redstone guidance system.

c. Jet Nozzle System. Because the Redstone missile passes through areas in which there is little atmospheric air, there is essentially no control exercised through the use of moveable control surfaces. Consequently, attitude control must be accomplished in another manner. To accomplish attitude control at high altitudes, a jet nozzle system is used. Located at the base of each body unit air vane are two jet nozzles mounted opposite to each other, which create a small thrust by exhausting air. When the air vanes move to correct an attitude error, the respective air jet nozzles are activated to create a force which rotates the missile about its center of gravity to the proper attitude. For example, if a pitch up error exists, air jets on opposite sides of the missile are operated, exhausting air downward to create an upward reaction which rotates the missile to the proper attitude.

17. PATH CONTROL

The inertial system senses errors from a predetermined reference trajectory. The path of the missile is adjusted during the latter portion of flight so that the actual impact point will coincide with that of the reference trajectory. The adjustment is brought about by signals generated by two accelerometers mounted on the stabilized platform. These accelerometers are air-bearing gyroscopic devices with pendulous masses and are single integrating mechanisms which sense accelerations and convert them to velocity outputs which are fed to the range and lateral computers. To obtain displacement information, the velocity signals are again integrated, this time by a ball and disc integrator in the computers. Then the control signals from the range and lateral computers are fed into the control computer previously mentioned.

a. Range Control. The range accelerometer is oriented on the stabilized platform so that it measures in a direction perpendicular to the trajectory tangent (impact coordinate) and in the plane of the trajectory. In this way, it can give velocity information pertaining to the location of the missile compared to the reference trajectory. Its output is fed to the range computer which performs the second integration for obtaining displacement, computes a corrected thrust termination time, and supplies arming signals for the warhead fuze. Any range error existing at cutoff, as well as deviations caused by various disturbances after cutoff, is measured, stored, and sent out as path corrections during the terminal guidance phase.

b. Lateral Control. The lateral accelerometer measures in a direction perpendicular to the plane of the trajectory and gives information as to the location of the missile compared to the plane of the reference trajectory. Deviations are measured along the entire trajectory and corrective signals are introduced into the control system of the missile during the initial and terminal phases of the flight.

18. LAYING

Since all path control information is determined by devices wholly within the missile, a precise degree of alinement of the stabilized platform on the firing azimuth is necessary. Fin I of the missile is pointed toward the target. Two theodolites and a missile prism are used to establish the precise firing azimuth by referencing to a previously surveyed orienting line. The missile prism is a reflector mounted on the missile and is alined to the missile airframe, as is the stabilized platform. The firing angle is established, and, then the missile, in the vertical position, is rotated until the missile prism can be sighted from one of the theodolites. After final adjustments, such as leveling the launcher to within a close tolerance, final laying of the missile is achieved. Since the missile prism is mechanically alined to the stabilized platform and since the missile has been rotated as a result of sighting on the prism from the theodolite in reference to the firing azimuth, the range and lateral accelerometers of the stabilized platform are oriented with respect to the target.

19. SEPARATION

During the preliminary designing of the missile, it became apparent that it would be advantageous if the body and thrust unit were separated after thrust termination. It was obvious that the high dynamic pressure encountered during descent toward the target becomes an important consideration in the design of the missile from the structural, aerodynamic, and control concepts, especially if the missile maneuvers during terminal guidance. It was determined that a large amount of structural weight in the thrust unit could be saved if it were constructed to meet only the conditions encountered during the ascending phase of flight when the speed of the missile is relatively slow. A separate re-entry section offers a more favorable center of pressure location over the wide range of velocities encountered thus improving stability. Control forces are less for the short and lighter body. For these reasons, provisions were made in the missile design for separation of the body and thrust unit after the powered flight phase is completed. The two units are connected until cutoff by six bolts, each containing an explosive charge in the head. Shortly after cutoff, the program device supplies a signal which detonates the bolts. At the same time, expulsion cylinders operate to supply the force to separate the two parts of the missile. This expulsion device is a piston and cylinder mechanism powered by compressed air.

20. TEMPERATURE CONTROL

Three temperature maintenance systems are used in the missile. The entire instrument compartment is heated or cooled as required to maintain a temperature of about 60° F prior to firing the missile. This is accomplished by a "drop tank." The drop tank, which is attached to the outside of the instrument compartment, contains a heater, a blower, and a dry ice tank. Air from the instrument compartment is routed in and out of the tank and either heated or cooled as required. The drop tank is released and falls to the ground when the firing switch is operated. Located inside the instrument compartment is an additional cooling system to maintain a uniform ambient temperature in the jacket surrounding the stabilized platform throughout the trajectory. The stabilized platform contains heating elements which help preheat it; the heat generated when the stabilized platform is operating is sufficient to keep it at the required temperature.

21. POWER SUPPLIES

The Redstone missile requires four types of electrical power for its operation.

a. 28-Volt Direct Current. Power to operate the rudder actuators, the various relays, valves, ignition circuits, and a 400-cycle alternating-current generator is obtained from two 28-volt direct-current batteries.

b. 60-Volt Direct Current. Power used in the guidance measuring and feedback circuits is provided by a 60-volt direct-current battery.

c. 115-Volt 400-Cycle Alternating Current. Power used in amplifier circuits and in the stabilized platform is provided by a 115-volt 400-cycle generator operated by one of the 28-volt direct-current batteries.

d. 208- and 115-Volt 60-Cycle Alternating Current. Power to operate the direct-current generators for use in testing and firing the missile and to operate the missile heaters is provided by a 60-kilowatt, 60-cycle, 208-volt, trailer-mounted diesel generator. This generator also supplies power to operate the propellant transfer equipment.

22. TRAJECTORY SEQUENCE

The Redstone follows a modified ballistic path which is divided into four phases (fig 8).

a. Phase I. The first phase of operation is the power phase during which the rocket engine is operating. During the first few seconds after liftoff, control of the missile is accomplished by rudders extending into the jet exhaust. Pitch programming begins to gradually incline the missile toward the target. Attitude and lateral control of the missile are exercised. Range information is used to determine the cutoff point. When the velocity and displacement of the missile are such that the missile will coast on to the target, the guidance system initiates action to turn off the propulsion system.

b. Phase II. Phase II is the period during which the missile settles to a free-flight condition. Then a signal from the program device causes the thrust and body unit to separate. Separation is accomplished by exploding 6 bolts which hold the units together and by 2 air-loaded pistons which push the units apart.

c. Phase III. During phase III, the missile is coasting to the target. Only attitude control is maintained, but range and lateral errors are determined and will be corrected just before impact. Since the missile is now in an atmosphere so rare that little or no control forces can be created by the rudders, air jet nozzles are used to maintain the proper attitude. These nozzles are mounted perpendicular to each air vane. Two or more are turned on as required to re-orient the missile. The resulting force is like that of a rocket motor creating thrust in the opposite direction of the flow.

d. Phase IV. The last phase of the trajectory begins at what is called re-entry, the point about 20 miles high where the missile meets enough air resistance to cause it to slow down. This air resistance causes a switch to operate which allows the range and lateral errors to be corrected.

Section IV. THE REDSTONE HANDLING EQUIPMENT

23. MISSILE TRANSPORTERS

The packaging and transportation equipment permits the missile and ground equipment to be moved by road, rail, water, and air. The missile is shipped from the production plant to the firing position in the same container and is checked out by the Ordnance Company without having to be completely removed from the container. The stabilized platform is packaged separately and is shipped by the manufacturer through the prescribed routes to the Ordnance Company. After conducting various tests, the Ordnance Company returns the stabilized platform to the package and sends it to the firing battery which has facilities for installation. The system includes a warhead shelter which is carried in a winterization vehicle. During inclement weather, this shelter is used when the stabilized platform is installed and when work is being performed at the guidance or warhead compartments. The missile transporters include--

a. Warhead Unit Semitrailer. This single-axle, 2-wheel, special vehicle provides storage protection and transportation for the warhead unit and also provides space for carrying the van cover jacks. In addition, all explosive items are carried in this container.

b. Aft Unit Trailer. The aft unit trailer, a single-axle, 2-wheel, special trailer, provides storage protection and transportation for the aft unit.

c. Thrust Unit Semitrailer. This single-axle, 2-wheel, special semitrailer provides storage protection and transportation for the thrust unit and storage and transport space for the van cover jacks and missile components which are installed at the firing position.

24. STABILIZED PLATFORM AND CARBON DIOXIDE TRUCK

The stabilized platform and carbon dioxide truck ($2\frac{1}{2}$-ton, 6x6, M35) provides transportation for 2,000 pounds of solid carbon dioxide (dry ice) in skid-mounted storage containers for use in temperature control of the missile guidance system. This vehicle is for transportation of the stabilized platform controlled container since direct-current power is available from the vehicle to heat the container if necessary.

25. CHECKOUT AND FIRING EQUIPMENT

The checkout and firing equipment is designed for the performance of functional tests and inspections of the missile to the extent necessary to insure the success of the mission. Artillery troubleshooting is limited to items which can indicate defective components which are easily replaced. Typical items in this category are amplifier boxes, solenoid valves, and the stabilized platform. These and certain other replaceable missile and ground equipment components are stored in spare parts vehicles which accompany the firing battery. The checkout and firing equipment includes--

a. Fire Control and Test Truck. The fire control and test truck ($2\frac{1}{2}$-ton, 6x6, shop van) accommodates a number of equipment racks and test panels for prefiring tests of the missile at the firing position and for performing periodic checks of missile components and systems maintained on a standby basis. This vehicle also serves as the center of the firing position communications. In addition, the fire control and test truck is used by the Ordnance Company along with other equipment that enables Ordnance to carry out more thorough checkout and troubleshooting procedures.

b. Battery Servicing Shop. The battery servicing shop (3 /4-ton, 2-wheel trailer) provides storage and transport to the firing position for missile batteries, battery service and test equipment, and other accessories. Battery activation operations are conducted within this trailer.

c. Power Distribution Station. The power distribution station (3/4-ton, 2-wheel trailer) provides a means of converting 208-volt, 3-phase, 60-cycle alternating-current electrical power required from the generator trailer to 28-volt direct-current, 60-volt direct-current, and 400-cycle electrical power for use in other items of ground equipment and in the missile during checkout.

d. Generator Trailer. The generator trailer ($2\frac{1}{2}$-ton, 2-wheel) provides a base for mounting of the Cummins diesel generator and accessory equipment. The generator provides 120-volt, single-phase, and 208-volt, 3-phase, 60-cycle electrical power to the power distribution station for conversion to required voltage, phase, and cycles for use in missile checkout procedures.

26. ACCESSORIES TRANSPORTATION TRUCK

The accessories transportation truck ($2\frac{1}{2}$-ton, 6x6,) serves as the prime storage and transport vehicle for loose items of equipment and accessories necessary for missile checkout and servicing at the firing position.

27. AIR COMPRESSOR TRUCK

The air compressor truck ($2\frac{1}{2}$-ton, 6x6,) serves as a base for mounting the air compressor, regulating system, and accessory equipment. The compressor provides compressed air at a specified dew point to the missile for testing and presssurizing before firing. The compressor truck contains a $1\frac{1}{2}$-cubic foot storage sphere.

28. FIRE TRUCK

The fire truck is used for emergency fire fighting. It provides a means of diluting or flushing away propellant spillage. This truck has an integral water tank storage capacity of 1,000 gallons and a pumping capacity of 1,500 gallons per minute (par 29). The fire truck is also the prime mover for the water tank trailer.

29. WATER TANK TRAILER

This 4 wheel trailer furnishes 2,000 gallons of reserve water to the fire truck. The fire truck supply together with that of the trailer permits pumping at maximum capacity for 2 minutes.

30. ERECTOR-SERVICER

The erector-servicer truck (fig 10) is a $2\frac{1}{2}$-ton, 6x6 truck which houses a 10-ton winch and 1-ton electric hoist. In addition to the truck, the erector-servicer consists of an H-frame, H-frame spreader bars, jack-type support stands, an A-frame, a rotating frame, a hydraulic cart with arresting cylinders, a winch, and erecting cables with associated pulleys and blocks. All of this equipment except the rotating frame (which is carried on the launcher) can be compactly stowed or mounted on the truck. This arrangement provides mobility, speed, and space and weight requirements for shipping as well as maneuverability in a tactical area. The purpose of the H-frame is to prevent the movement of the truck with respect to the launcher during assembly and erection of the missile. After the missile is erected, the H-frame is also used as a boom for positioning and supporting the service platform. The A-frame is employed as a boom for lifting and positioning the aft unit to the warhead unit, for lifting and positioning the rotating frame assembly to the thrust unit, and for lifting and suspending the thrust unit for mating to the body. The rotating frame assembly (commonly called the tilt ring) is secured to the rear of the thrust unit and attached to the launcher. The tilt ring serves as a hinge during missile erection. When the missile is prepared for erection, the A-frame, with the cables attached, is approximately vertical. Winch power is then applied to the A-frame which erects the missile by functioning as a lever arm for the erection force transferred through the cables. The A-frame pivots on the launcher in the direction of the truck and raises the missile, and when the A-frame is almost horizontal, the missile is erected. After the missile is erected, rollers on the tilt ring permit rotation of the missile on the launcher to the correct firing azimuth.

9. LAUNCHER

The launcher, consisting of a base, deflector plate, and rotating frame assembly (tilt ring), is mounted at the outrigger support arms to a movable single axle. This arrangment provides mobile capability to the launcher base when the unit is towed behind the truck and furnishes a means for quickly disconnecting the wheel and axle assembly, when the launcher is emplaced at the firing position.

32. PROPELLANT VEHICLES

Propellant handling and transportation equipment has been designed and selected for long distance road travel and limited cross-country movement. The transfer equipment fills the missile tanks rapidly and conveniently. The regular electrical power source at the firing position is used to drive the propellant pumps. The propellants are alcohol, liquid oxygen, and hydrogen peroxide. The liquid oxygen is pumped from the generating plant where it is produced directly into the trailers which deliver it to the firing position, whereas the hydrogen peroxide is carried in the original container supplied by the manufacturer. The alcohol is normally shipped to Ordnance in 55-gallon drums, and, from the drums, it is transferred to a trailer in which the alcohol is mixed with water. The propellant vehicles include--

a. Alcohol Tank Semitrailer. The alcohol tank semitrailer (2-wheel, 3, 000-gallon tank) provides storage, transport, and pumping facility for the 75 percent alcohol, 25 percent water fuel mixture. The fuel transfer equipment is mounted in a closed compartment at the rear of the trailer and provides means of metering, filtering, and transferring the fuel to the missile at the firing site.

b. Liquid Oxygen Semitrailer. The lox semitrailer (2-wheel, 9-ton, tank, special) provides storage, transport, and pumping facility for the lox. This lox transfer equipment is mounted in a closed compartment at the rear of the trailer. Initial filling of the missile tank at the firing position and final filling to replenish evaporation losses is accomplished from the lox semitrailer.

c. Hydrogen Peroxide Servicer. The hydrogen peroxide servicer (3/4-ton, 4x4) provides transport and a means of handling the 78-gallon drum of concentrated hydrogen peroxide and maintining it at a temperature of $75° F \pm 10° F$ by using the heater and cooler kits included with the truck. The pumping equipment when connected to the alternating - current power source is used to transfer the H_2O_2 to the missile at the firing position.

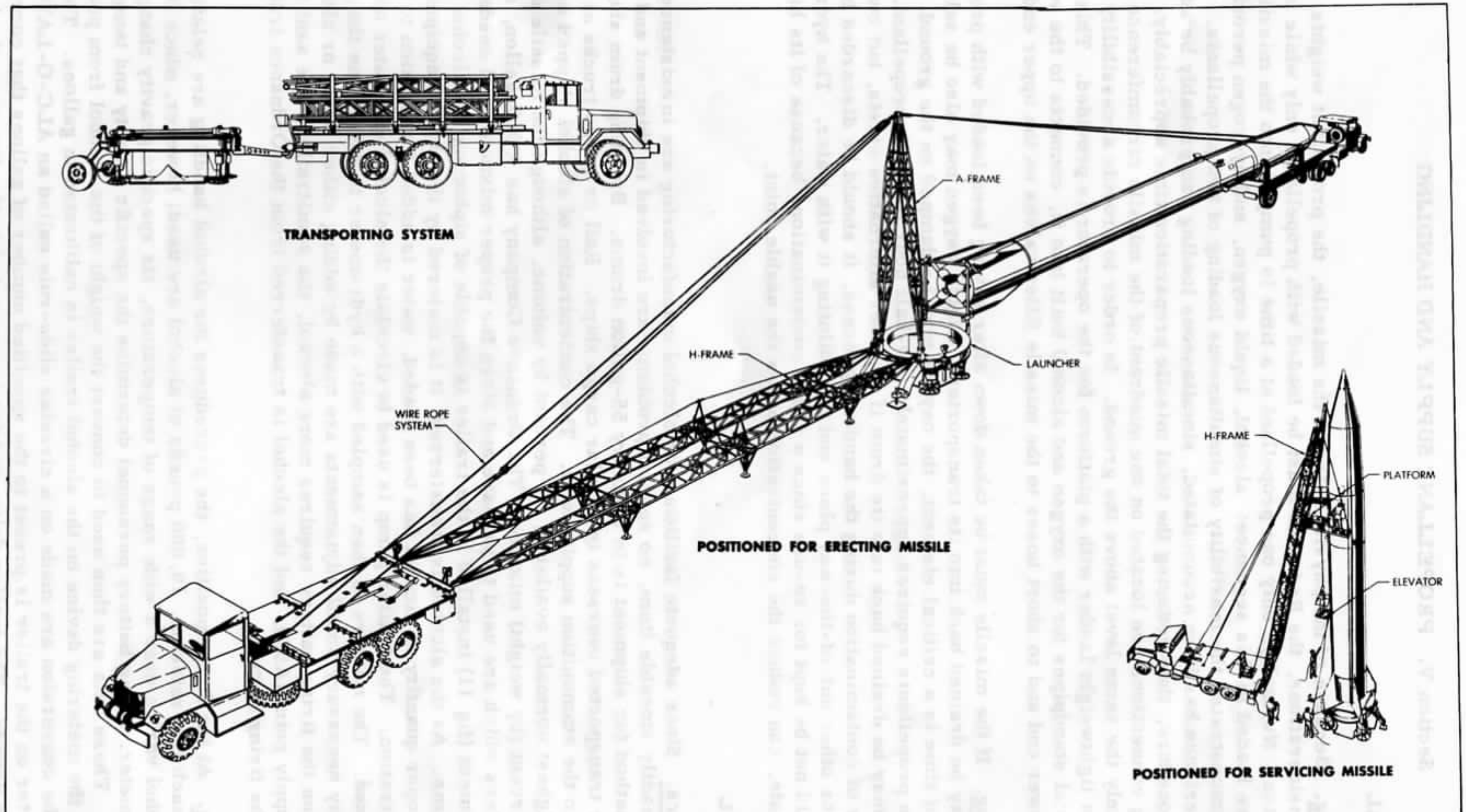

Figure 10. Erector servicer truck.

Section V. PROPELLANT SUPPLY AND HANDLING

33. GENERAL

a. Loading. Because of the physical size of the missile, the propellant weights, and structural considerations, the Redstone must be loaded with propellants only while in the vertical position. Normally, only one propellant at a time is pumped into the missile. The propellants are loaded in this sequence: alcohol, liquid oxygen, and hydrogen peroxide. Tests have demonstrated the feasibility of simultaneous loading of two propellants. When sufficient experience has been accumulated, simultaneous loading can probably be adopted as a standard procedure, thus reducing the total missile preparation time appreciably. All missile filling connections are located on one quadrant of the missile circumference and are at approximately the same level above the ground. In order to provide accessibility to these connections, a lightweight ladder with a platform for the operator is provided. This ladder, with the vertical standpipes for the oxygen and alcohol built into it, connects to the vehicle hose on the lower end and to short hoses to the missile filler valves on the upper end.

b. Draining. If the missile must be taken down after having been loaded with propellants, the alcohol may be drained back into its transporter. Liquid oxygen may also be salvaged. If the saving of time is a critical element, the oxygen may be dumped on the ground. The draining of the propellants requires approximately one-half hour for each propellant. Hydrogen peroxide may be drained back into its drum if no other alternative exists, but owing to the possibility of contamination during the handling process, it should be discarded by dumping in a ditch or other out-of-the-way place and then diluting it with water. The hydrogen peroxide should not be kept for re-use since a slight contamination, because of its high decomposition rate, can reduce the concentration below the usable point.

34. ALCOHOL

a. Logistics. Since adequate facilities for alcohol manufacturing are in existence and alcohol is a readily storable item, no special problems are involved in shipment and storage. The normal method for shipment is in ordinary 55-gallon drums. By using drum shipment, alcohol can be transported overseas in regular cargo ships. Rail or cargo trucks are used to forward it to the ammunition supply point. The concentration of alcohol shipped in the drum is the highest normally available, 95 percent by volume, although the missile only requires a 75 percent (by weight) mixture. The Ordnance Company has 3, 000-gallon, alcohol tank semitrailers which are used to prepare and store the proper mixture until needed. The pumping equipment (fig 11) installed in the trailer is capable of siphoning the alcohol from the supply drums. As the alcohol is transferred, it is metered by the trailer equipment. As soon as the proper quantity of alcohol has been loaded, water is added for dilution to the proper concentration. The trailer pump is used to circulate the alcohol and water until it is thoroughly mixed. The mixture is then sampled with a hydrometer to determine the concentration, and any necessary small adjustments are made by adding either water or alcohol, as required. When the firing battery requires more alcohol, the semitrailers are sent to the ammunition supply point (ASP), and the alcohol is transferred from the Ordnance trailers into those of the firing battery.

b. Loading. At the firing position, the procedures for alcohol handling are relatively simple. For each fire mission, 19, 000 pounds of alcohol are used; however, since the volume of alcohol varies over a wide range of temperature, its specific gravity changes. Using a hydrometer, firing battery personnel determine the specific gravity and temperature of the alcohol. These data are then used to convert the weight of the alcohol from pounds to gallons, since the metering device on the alcohol trailer is calibrated in gallons. The computations for the conversion are made on a circular slide-rule called an ALC-O-LATOR. Finally the meter on the trailer is preset to the specified number of gallons that corresponds to the weight in pounds. The trailer delivery hose is connected to the fitting on the lower end

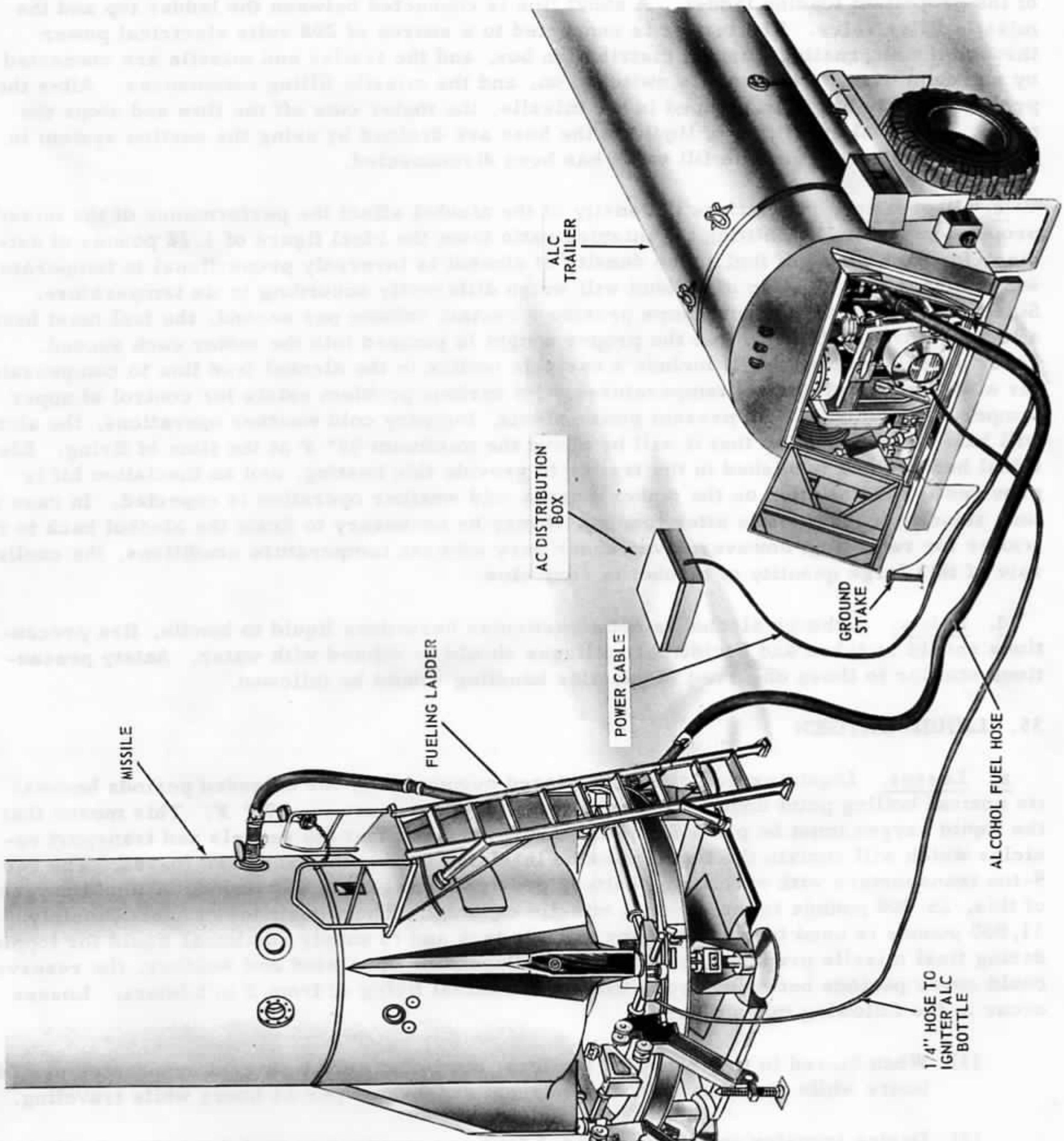

Figure 11. Alcohol loading.

of the propellant loading ladder. A short line is connected between the ladder top and the missile filler valve. The trailer is connected to a source of 208 volts electrical power through the alternating-current distribution box, and the trailer and missile are connected by a ground wire. The pump is switched on, and the missile filling commences. After the proper quantity has been pumped in the missile, the meter cuts off the flow and stops the pump. Residual quantities of liquid in the hose are drained by using the suction system in the trailer after the missile fill valve has been disconnected.

c. Preheating. Variations in density of the alcohol affect the performance of the missile propulsion system by shifting the mixture ratio from the ideal figure of 1.28 pounds of oxidizer for each pound of fuel. The density of alcohol is inversely proportional to temperature, which means that a gallon of alcohol will weigh differently according to its temperature. Since the missile propellant pumps provide a certain volume per second, the fuel must have a temperature of 95° F so that the proper weight is pumped into the motor each second. Later propulsion plants will include a variable orifice in the alcohol feed line to compensate for a wide range of alcohol temperatures. No serious problem exists for control of upper temperature limits. With present power plants, for very cold weather operations, the alcohol will have to be heated so that it will be above the minimum 95° F at the time of firing. Electrical heaters are furnished in the trailer to provide this heating, and an insulation kit is provided for installation on the tanker when a cold weather operation is expected. In case of long standby of the missile after loading, it may be necessary to drain the alcohol back to the trailer for reheating; however, even under very adverse temperature conditions, the cooling rate of this large quantity of alcohol is very slow.

d. Safety. Although alcohol is not a particular hazardous liquid to handle, fire precautions should be taken and accidental spillages should be diluted with water. Safety precautions similar to those observed in gasoline handling should be followed.

35. LIQUID OXYGEN

a. Losses. Liquid oxygen cannot be stored economically for extended periods because its normal boiling point under standard atmospheric pressure is -297° F. This means that the liquid oxygen must be produced in the Army area and that the vessels and transport vehicles which will contain the liquid must be insulated to prevent excessive losses. The two 9-ton transporters with each firing battery provide a total of 36,000 pounds of liquid oxygen; of this, 25,000 pounds is the nominal missile capacity. The remainder of approximately 11,000 pounds is used to cool down the missile tank and to supply additional liquid for topping during final missile preparation or standby. Depending upon wind and weather, the reserve could cover periods between oxygen filling and actual firing of from 2 to 6 hours. Losses occur in the following magnitudes:

(1) When stored in the transport trailers, approximately 1 percent evaporates per 24 hours while standing and 2 to 3 percent evaporates per 24 hours while traveling.

(2) During transfer approximately 2.5 tons are required to cool down the missile tank, transfer lines, pumps, etc.

(3) During standby while the missile is loaded, approximately 30 pounds per minute are lost from the missile tank, dependent on environmental conditions.

b. Production. The supply and field production of liquid oxygen is the responsibility of the Engineer Company. The general scheme of production consists of compression of air, cooling it by refrigeration, and then passing it to an expander valve where it is cooled to liquefaction temperatures by expansion. The liquid air is then passed to a rectification column where separation of the oxygen and nitrogen takes place by fractional distillation.

c. Liquid Oxygen Semitrailer. For transportation of the liquid oxygen between the production plant and the firing position, a 9-ton capacity semitrailer is used. This unit was developed by the Corps of Engineers for this purpose. It includes a vacuum insulated container, a transfer system with electrically driven pump, and other accessories. In order to prevent pump cavitation, the liquid container must be pressurized. This is done by allowing some liquid oxygen to flow into a finned tube coil exposed to the atmosphere, where the liquid evaporates. The resulting gas is fed back into the tank vapor space until the required pressure is reached. An automatic valve is also in the system to permit the pressurization to be remotely controlled for topping of the missile tanks from the firing panel.

d. Loading. At the firing position, the two trailers are connected to a Y-connection by metallic hoses supplied with the vehicle (fig 12). The outlet of the Y is connected to the loading ladder standpipe, which is, in turn, connected to the missile filler valve. As soon as the connections are made, the operator starts building pressure in the trailer tank. He also opens the tank discharge valve to allow the liquid oxygen to flow by gravity and pressure through the pump, hoses, and missile to commence the precooling. As soon as the precooling of lines and pump is well along, as indicated by the frost buildup on these items, the pump is started and the liquid transfer takes place. The pump in one trailer is started a few minutes earlier than the other to insure that all of the topping reserve remains in one of the trailers. Filling of the missile is indicated by overflow of liquid from the vent pipe, whereupon the pumps are shut down and the hoses and accessories are removed. The trailer containing the reserve liquid is moved to the topping position, which is near the compressor truck. The topping line is connected and the pressure control line is installed. From this time on, oxygen can be topped into the missile when required during the firing procedures.

e. Safety. Handling of liquid oxygen produces no undue hazards if certain precautions are taken. The vapors are nontoxic and noncombustible; however, they support combustion of a wide variety of materials at an extremely rapid rate. It is necessary to ventilate thoroughly clothing of personnel who have been exposed to large concentrations of oxygen gas before allowing smoking and contact with open flame. Five to ten minutes in the open air will serve to dissipate any gases permeating the clothing, particularly if the dissipation is assisted by brushing. Contact of the liquid with exposed flesh produces rapid freezing, and injuries similar to a burn will result. Asbestos gloves and goggles or a face mask should be worn by the personnel handling liquid oxygen. All equipment used must be free of grease, oils, solvents, and organic material.

36. HYDROGEN PEROXIDE

a. Storage. Hydrogen peroxide (H_2O_2) in the pure form is a stable chemical, but contamination can cause rapid decomposition. For this reason it is shipped from the manufacturer to the missile in a single container to reduce the possibility of contamination which could result from transferring the liquid. A 78-gallon aluminum drum is used for storage and shipment of hydrogen peroxide because this capacity is enough for one missile filling. The drum features a double head with a fill and vent opening. The design chosen has received the approval of government agencies responsible for road, rail, and overseas shipment of hazardous materials. Hydrogen peroxide will be received and stored at the ammunition supply point. The drums should not be stacked and should be spaced to allow easy access for inspection or removal. Periodic checks must be made, and any drum showing a steady increase above ambient temperature should be isolated and handled in accordance with the pertinent safety regulations.

b. Hydrogen Peroxide Servicer. The hydrogen peroxide drum will be transported to the firing position in a slightly modified 3/4-ton cargo truck (fig 13) capable of carrying two drums of hydrogen peroxide. To insure proper performance of the missile power plant, the peroxide must be at a temperature of 75° F $\pm$ 10° F, at the time of filling. The peroxide

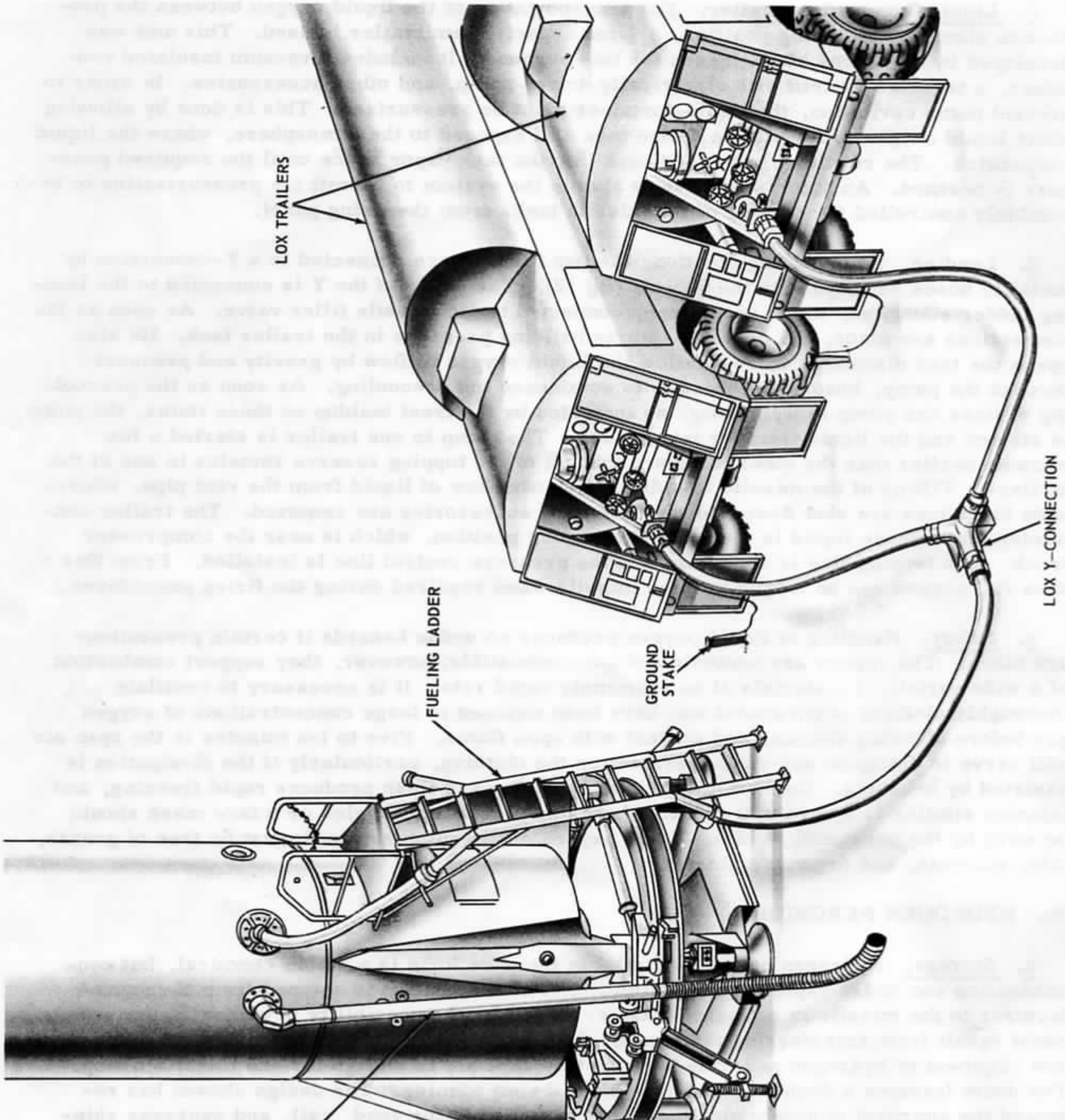

Figure 12. Liquid oxygen loading.

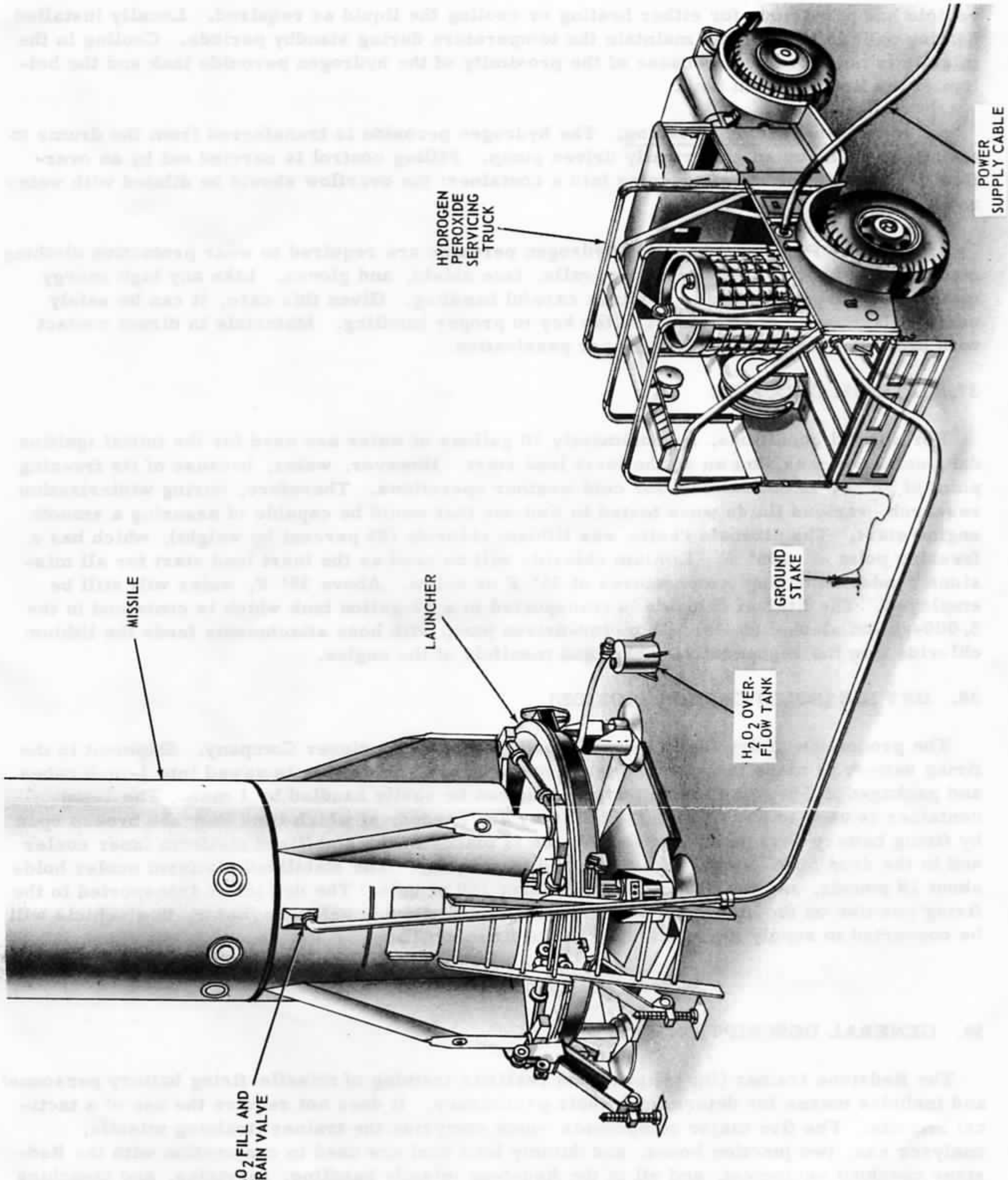

Figure 13. Hydrogen peroxide loading.

vehicle has provisions for either heating or cooling the liquid as required. Locally installed heating pads in the missile maintain the temperature during standby periods. Cooling in the missile is not a problem because of the proximity of the hydrogen peroxide tank and the bottom of the liquid oxygen tank.

c. Hydrogen Peroxide Loading. The hydrogen peroxide is transferred from the drums to the missile tank by an electrically driven pump. Filling control is carried out by an overflow device with the overflow going into a container; the overflow should be diluted with water and dumped.

d. Safety. Personnel handling hydrogen peroxide are required to wear protective clothing consisting of boots, flame proof coveralls, face shield, and gloves. Like any high energy material, hydrogen peroxide requires careful handling. Given this care, it can be safely used. Cleanliness of equipment is the key to proper handling. Materials in direct contact with hydrogen peroxide require proper passivation.

37. LITHIUM CHLORIDE

For normal conditions, approximately 10 gallons of water are used for the initial ignition dampening process, known as the inert lead start. However, water, because of its freezing point of 32° F, is not suitable for cold weather operations. Therefore, during winterization research, various fluids were tested to find one that would be capable of assuring a smooth engine start. The ultimate choice was lithium chloride (25 percent by weight), which has a freezing point of -105° F. Lithium chloride will be used as the inert lead start for all missions conducted during temperatures of 35° F or below. Above 35° F, water will still be employed. The lithium chloride is transported in a 20-gallon tank which is contained in the 3, 000-gallon alcohol trailer. A motor-driven pump with hose attachments feeds the lithium chloride into the regenerative jacket and manifold of the engine.

38. DRY ICE (SOLID CARBON DIOXIDE)

The production of dry ice is the responsibility of the Engineer Company. Shipment to the firing battery is made in 1-ton insulated containers. The dry ice is sawed into 1-inch cubes and packaged in 50-pound insulated bags that can be easily handled by 1 man. The 1-ton container is used to store the bags until they are needed, at which time they are broken open by firing battery personnel, and the dry ice is placed in the stabilized platform inner cooler and in the drop tank. Both tanks are filled to capacity. The stabilized platform cooler holds about 18 pounds, and the drop tank holds about 150 pounds. The dry ice is transported to the firing position on the stabilized platform and carbon dioxide vehicle. Later, this vehicle will be converted to supply liquid nitrogen to the firing position.

Section VI. THE REDSTONE TRAINER

39. GENERAL DESCRIPTION

The Redstone trainer (fig 14) provides realistic training of missile-firing battery personnel and includes means for determining their proficiency. It does not require the use of a tactical missile. The five major components which comprise the trainer (training missile, analyzer van, two junction boxes, and dummy load box) are used in conjunction with the Redstone checkout equipment, and all of the Redstone missile handling, servicing, and launching equipment can be used with the training missile (fig 14).

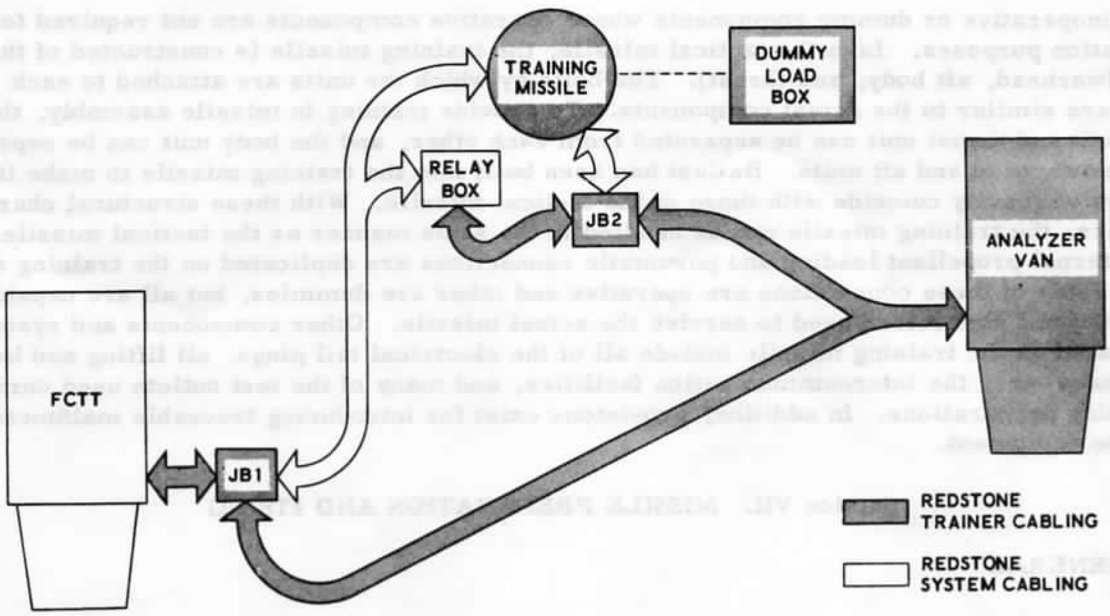

Figure 14. Redstone trainer.

40. OPERATION

a. Simulation. In operation, command signals from the Redstone checkout equipment are intercepted in the two trainer junction boxes and sent to the analyzer van, where simulation signals are produced. The simulation signals are substituted for the output signals normally provided by the missile, and are sent to the checkout equipment in the fire control and test truck (FCTT) through the junction boxes. Missile operations are simulated fully by these means, and, in addition, simulation equipment in the training missile presents audible and visual representation of the operation of various missile components as they respond to command signals from the fire control and test truck.

b. Malfunctions. The trainer also provides simulation of indication and traceable malfunctions. These two types of malfunctions are initiated by operation of controls in the analyzer van and provide training in the detection and tracing of equipment malfunction.

c. Recording. A complete record of the operations performed by members of the firing battery is furnished by the automatic printer and the magnetic tape recorder in the analyzer van. The automatic printer records the use of all controls operated by firing-battery personnel and the elapsed time during an operation, as well as out-of-sequence use of such controls. The magnetic tape recorder system employs handy-talkie radios (supplied with the trainer) and permits the recording of all conversations that occur during a training exercise.

d. Dummy Load. The dummy load box provides the same electrical responses as the training missile. Therefore, it can be substituted for the training missile for training in missile checkout, and the training missile can be used elsewhere for other phases of training (i.e., missile handling, erection, etc.). A dummy relay box is supplied for use with the training missile during handling and erection practice.

41. THE TRAINING MISSILE

The external appearance of the training missile, including movable rudders and air vanes, closely resembles that of the tactical missile. Most of the interior details are duplicated,

using inoperative or dummy components where operative components are not required for simulation purposes. Like the tactical missile, the training missile is constructed of three units (warhead, aft body, and thrust). The bolts by which the units are attached to each other are similar to the actual components. To provide training in missile assembly, the body unit and thrust unit can be separated from each other, and the body unit can be separated into the warhead and aft units. Ballast has been built into the training missile to make its centers of gravity coincide with those of the tactical missile. With these structural characteristics, the training missile can be handled in the same manner as the tactical missile. All external propellant loading and pneumatic connections are duplicated on the training missile. Some of these connections are operative and other are dummies, but all are capable of receiving the connectors used to service the actual missile. Other components and systems duplicated on the training missile include all of the electrical tail plugs, all lifting and handling hardware, the intercommunication facilities, and many of the test outlets used during launching preparations. In addition, provisions exist for introducing traceable malfunctions into the equipment.

Section VII. MISSILE PREPARATION AND FIRING

42. GENERAL

This section contains a general discussion of the firing area operations in the typical sequence. Tactical considerations may dictate other sequences. After the launcher position is selected, the other equipment is located in positions near the launcher generally dictated by the lengths of cables and hoses. Generally, one side of the area is free of equipment so that the propellant servicing equipment may be readily brought into position to load the missile as rapidly as possible.

43. OCCUPATION OF POSITION

a. Launcher. A centerline is established by using a light rope for the intended position of the erector-servicer and missile unit trailers. This is done to facilitate missile assembly. The line is laid to cross the center of the launcher position stake. The erector-servicer truck tows the launcher into the firing position (fig 15). The launcher is emplaced directly over the stake so that the erector-servicer can be assembled easily without encountering alinement problems between the launcher and truck. The wheel and axle assembly is removed from the launcher. The support pads are seated, and jacks in the launcher legs are used to level the launcher. Three additional stabilizing pads are emplaced.

b. Erector-Servicer. The hydraulic cart, arresting cylinders, A-frame cables, hoists, and other equipment are unloaded near the launcher. The erector-servicer truck is then positioned on the opposite side of the launcher. The H-frame sections are unloaded, connected to the launcher and assembled. The truck is driven forward along the centerline to the proper position so that the assembled H-frame can be fastened to the aft end of the truck. The A-frame and cabling systems are then assembled.

c. Power Equipment. The generators, battery servicing shop, and power distribution station are usually emplaced in one area ahead of the erector-servicer truck. The generators and power distribution station are required for missile firing; so the power equipment should be as far from the launcher as cable lengths permit (about 200 feet).

d. Air Compressor. The air compressor is generally emplaced near the power equipment. The air hose from the compressor to the launcher valve box is 200 feet long. The air compressor (or air servicer when it becomes available for tactical use) must remain in the firing position for missile pressurization just prior to firing.

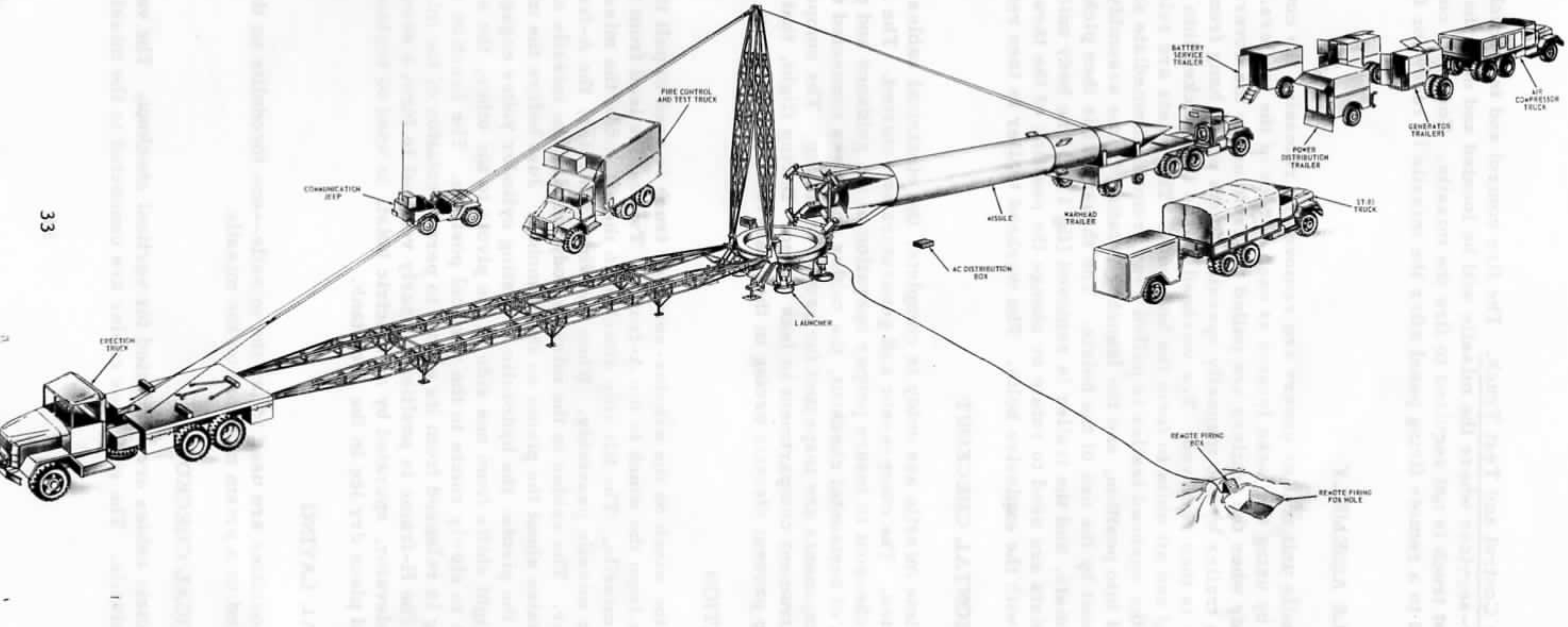

Figure 15. Firing position.

e. Fire Control and Test Truck. The fire control and test truck is emplaced parallel to the erector-servicer where the missile will be located and near the launcher. The fire control and test truck is not required to fire the missile. Complete control of the missile is transferred to a remote firing panel after the missile is ready for firing. The truck is then removed.

44. MISSILE ASSEMBLY

The missile unit trailer covers are removed by releasing the covers and raising them a few inches by using the jacks located at each corner of the trailers. The units are exposed for assembly when the trailers are pulled out from under the covers. The aft unit is picked up from its trailer by two manually operated hoists which hang from the A-frame (fig 16). The trailer is then removed. The warhead unit is then backed into position to permit joining the warhead and aft units to form the body unit. The hoists are released, and the body unit resting on the warhead trailer is pulled away from the immediate area. The thrust unit is then backed into position, and the launcher rotating frame assembly (tilt ring) is attached to the thrust unit by the use of the hoists. The thrust unit is then picked up from its trailer by using the hoists, and the trailer is removed (fig 17). The body unit is then backed into position; the hoists are used to rotate or change the position of the thrust unit and the two units are joined with the explosive bolts. The warhead trailer is then removed.

45. HORIZONTAL CHECKOUT

By the time missile assembly is complete, the electrical cables and air lines are laid out and connected. The compressor and generators are started. The missile is then given a horizontal checkout to insure proper operation of the guidance and propulsion systems. Upon completion of horizontal checkout, the cables and hoses connected to the missile are removed. Missile components are inspected for proper mounting. The compartment doors are closed, and the instrument compartment is leak tested. During flight, that compartment is pressurized to help prevent electric arcing in the near-vacuum trajectory. The drop tank is installed.

46. ERECTION

The 10-ton winch on the erector-servicer truck is used to pull the erection cables. A cable leads from the winch to the A-frame. Two cables lead from the A-frame to the body unit of the missile. The tilt ring attached to the aft end of the missile is mounted on its pivots after missile assembly. When the winch operates, the A-frame rotates on pivots on the launcher. The cables to the missile body unit lift the missile nose; the aft end of the missile rotates about the pivots on the launcher. Just before the missile center of gravity shifts past the pivots, the hydraulic arresting cylinder yokes engage the tilt ring. When the missile weight shifts from one side of the pivots to the other, the arresting cylinders allow the missile to slowly rotate to the vertical position. The erection cabling is removed, and the tilt ring is released from its pivots to permit rotation of the missile to the proper firing azimuth. The H-frame is positioned nearly vertical to form a servicing platform and elevator. The elevator, operated by an electric hoist, is used to replace guidance system components and place dry ice in the drop tank.

47. INITIAL LAYING

Two theodolites are used to lay the missile--one theodolite on the orienting line and the other sighted on a prism mounted on the missile.

48. VERTICAL CHECKOUT

The electric cables are connected for vertical checkout. The valve box lines are connected to the missile. The relay box cables are connected to the missile. The rudders are

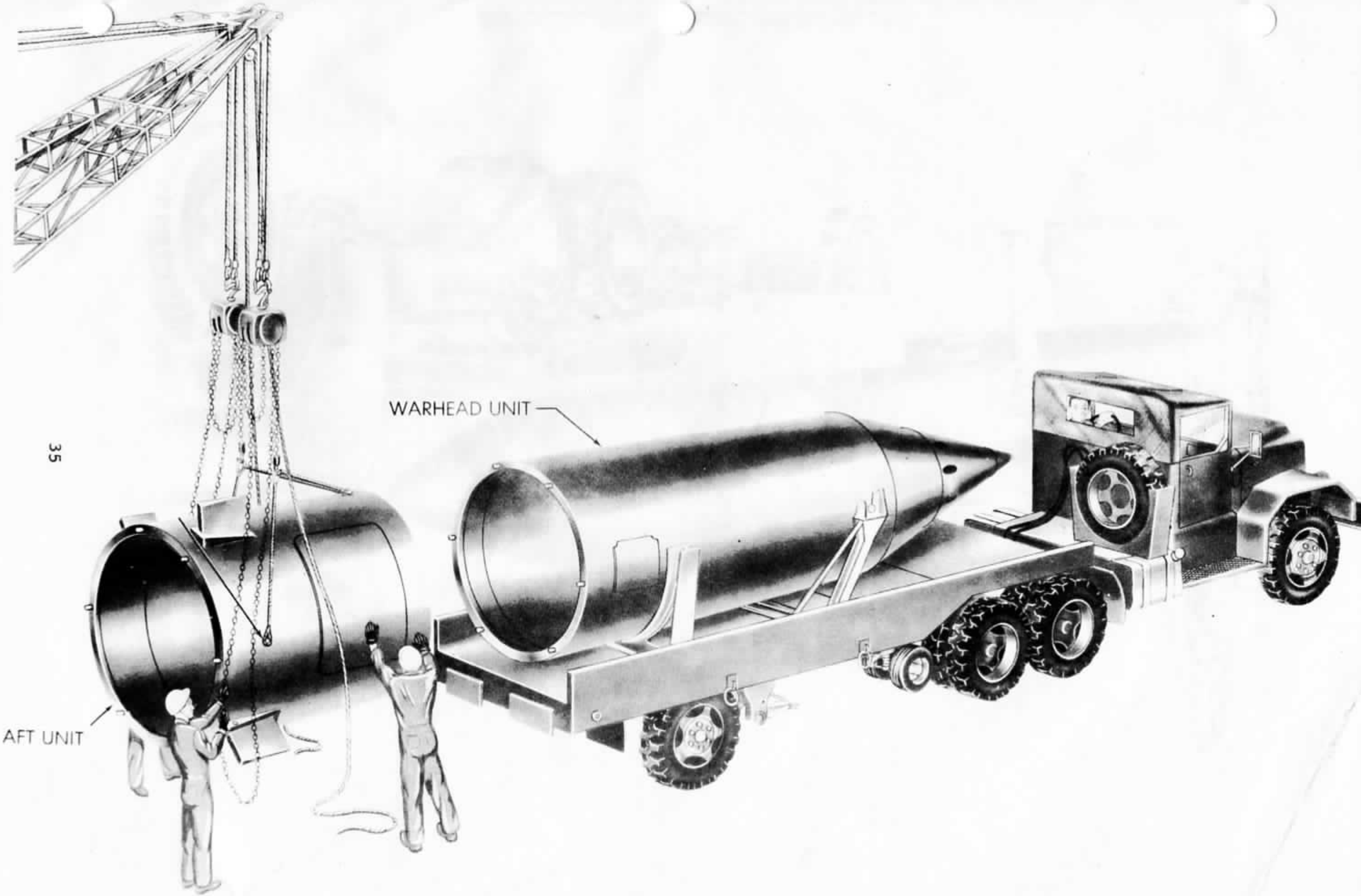

Figure 16. Attaching aft unit to warhead unit.

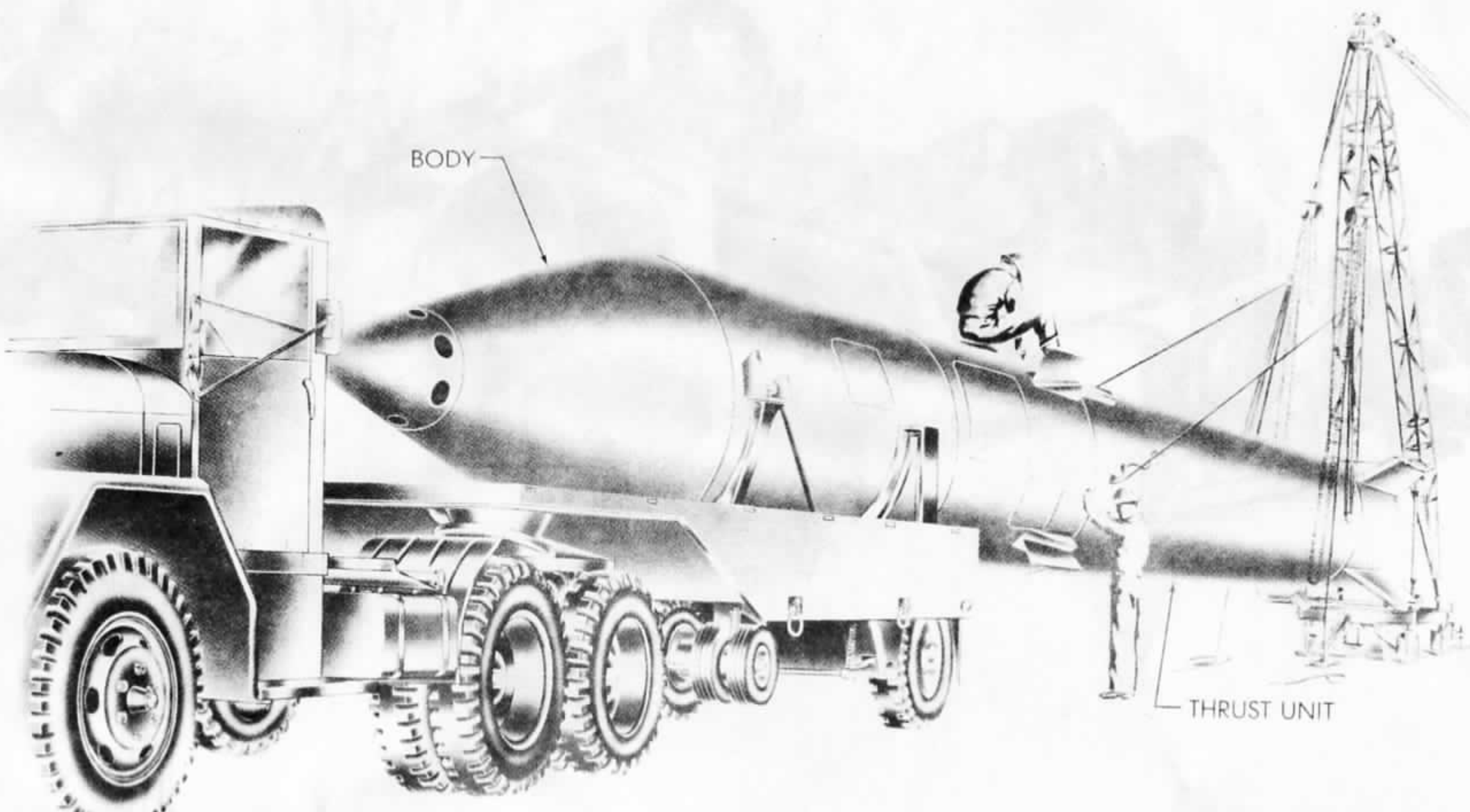

Figure 17. Attachi thrust unit to body unit.

installed. A vertical checkout consisting mainly of power tests, stabilized platform tests, and simulated flight tests in conducted. The fire mission data are inserted into the computers and program device.

49. PROPELLANT LOADING

Propellant loading is conducted immediately after vertical checkout. However, the lox overflow pipe, lox replenishing pipe, and propellant loading ladder are installed as soon as the missile is laid. The hoses from the top of the ladder are connected to the missile fill valves. The alcohol is loaded first; the proper quantity in gallons is preset on a flow meter, located in the alcohol semitrailer, and the pump is started. The flow meter turns off the pump when the preset quantity has been transferred. The alcohol equipment is then removed from the area. Liquid oxygen is loaded from two 9-ton semitrailers. The proper quantity of lox had been transferred when overflow occurs from a standpipe within the lox tank. The standpipe is set at the proper level by a height adjustment mechanism. Liquid oxygen density is mainly a function of pressure so the standpipe is set to compensate for the nominal atmospheric pressure at the firing position altitude. After the liquid oxygen is transferred, one liquid oxygen semitrailer is positioned for replenishing which will occur at X-5 minutes. Hydrogen peroxide is pumped from the 78-gallon drum on the truck until overflow occurs from the hydrogen peroxide tank in the missile. No adjustments of quantity are required.

50. FINAL PREPARATION FOR FIRING

The missile is given a final laying to insure that it has not rotated or twisted during propellant loading (fig 18). The igniter squib, mainstage stick, and initial control rudders are installed. The drop tank is reloaded with dry ice. Control of the missile is transferred from the fire control test truck to the firing panel, and the fire control test truck is disconnected and removed from the area. The erector-servicer is removed from the area. The missile is pressurized, the liquid oxygen is replenished, and the fire switch is activated. If ignition is not satisfactory, the propulsion system is either automatically cut off by the ignition system or manually cut off from the remote firing panel if necessary.

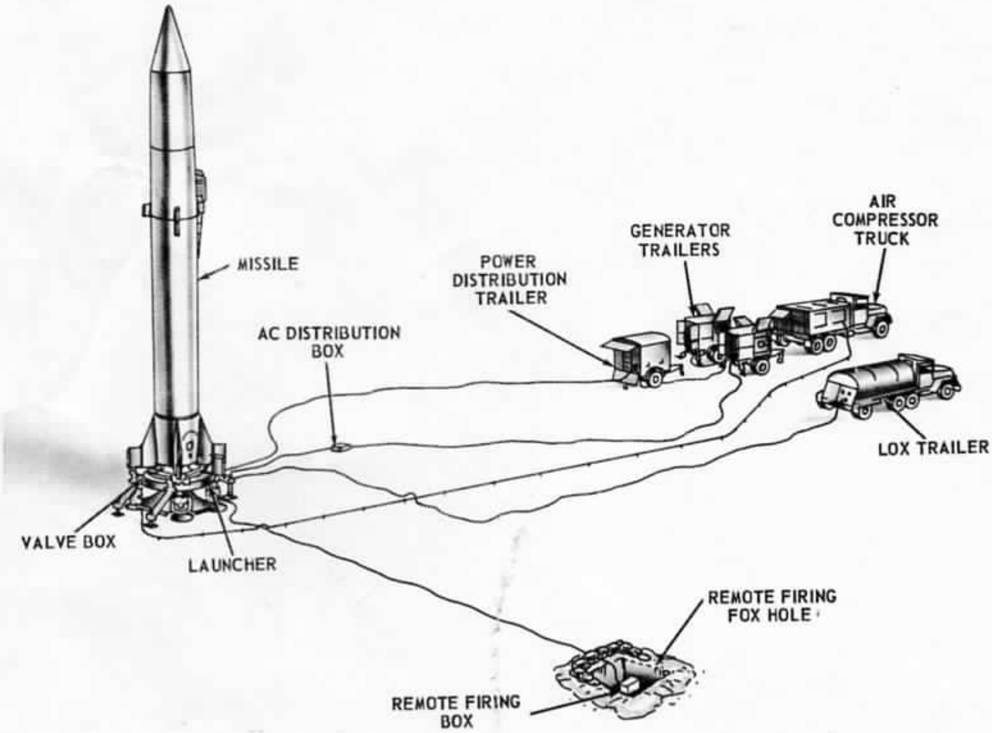

Figure 18. Final preparation for firing.

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